EFFECTS OF POSTHARVEST HEAT AND ANOXIC TREATMENTS ON THE MANIFESTATION OF CHILLING INJURY IN 'BERANGAN' BANANA

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By
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ENDORSEMENT

The project report entitled **Effects Of Postharvest Heat And Anoxic Treatments On The Manifestation Of Chilling Injury In 'Berangan' Banana** by **Megat Hazeq bin Megat Hashimi** Matric Number **UK16174** has been reviewed and corrections have been made according to the recommendations by examiners. This project is submitted to the Department of Agrotechnology in partial fulfillment of the requirement of degree of Science in Agrotechnology (Post Harvest Technology) Faculty of Agrotechnology and Food Science, Universiti Malaysia Terengganu.

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ABSTRACT

Chilling injury is a serious disorder that can be observed in plant tissues, especially those of tropical and subtropical origin. One of the most susceptible produces to chilling injury is banana which resulted in the blackening of the peel from the exposure of susceptible banana tissues to temperature lower than 15°C. However the critical temperature at which chilling injury symptoms are manifested varies among different cultivars and commodities. Chilling injury causes the release of metabolites , such as amino acids and sugar , and minerals from cells and together with the degradation of cell structure. This study was carried out to investigate the effects of different post harvest treatments to reduce the manifestation of chilling injury in 'Berangan' banana. The treatments involved were hot water treatment at 50°C, hot air treatments at 30°C and 50°C, anoxic treatment and bananas without any treatment were served as control. The treated bananas were stored at 13°C; RH 90% for 3 weeks followed by storage at ambient (25±1°C) for another one week. The physico-chemical analyses and the manifestation of chilling injury were observed at weekly intervals. The total color change of the pulp and peel, chilling injury scores, and TBA values were increasing over the storage time. Peel to pulp weight ratio and firmness were decreasing over the storage time. However among all the treatments, the best treatment for extending shelf life and reducing the manifestation of chilling injury in 'Berangan' banana was observed to be the anoxic treatment followed by hot water treatment at 50°C, hot air treatments at 50°C, control and lastly hot air treatments at 30°C.

ABSTRAK

Kecederaan sejuk-dingin adalah satu kerosakan yang boleh dikesan pada tisu tumbuhan, terutamanya tumbuhan tropika dan subtropika. Salah satu produk pertanian yang mudah terkena kecederaan sejuk-dingin adalah pisang yang akan menyebabkan terjadinya kehitaman pada kulit pisang yang diletakkan pada suhu rendah daripada 15°C. Walau bagaimanapun, suhu kritikal yang akan menyebabkan terjadinya simptom-simptom ini adalah berbeza mengikut kultivar dan komoditi. Kecederaan sejuk menyebabkan pelepasan metabolik, seperti amino asid dan gula, dan mineral dari sel dan bersama-sama ini menyebabkan kerosakan struktur sel. Kajian ini dijalankan adalah untuk mengkaji kesan terhadap rawatan lepas tuai yang berbez-beza untuk mengurangkan kejadian kecederaan sejuk-dingin pada pisang Berangan. Rawatan tersebut melibatkan rawatan air panas pada 50°C, rawatan udara panas pada suhu 30°C dan 50°C, rawatan anoksik dan juga tanpa rawatan yang akan bertindak sebagai kawalan. Pisang yang telah dirawat disimpan pada suhu 13°C; RH 90% untuk 3 minggu dan diikuti dengan penyimpanan pada suhu bilik (25$\pm$1°C) untuk satu minggu. Analisis yang melibatkan analisis fiziko-kimia dan juga kewujudan kecederaan sejuk-dingin diperhatikan pada sela masa satu minggu. Jumlah keseluruhan perubahan warna pada isi dan kulit, skor bagi kerosakan sejukidingin, dan bacaan asid thiobarbiturik (TBA) sepanjang masa penyimpanan. Nisbah berat kulit kepada isi dan kekerasan adalah menurun sepanjang tempoh tersebut. Walaubagaimanapun, dalam kesemua rawatan yang telah dijalankan, rawatan yang terbaik dalam memanjangkan jangka hayat dan mengurangkan kewujudan kecederaan sejuk-dingin pada pisang Berangan adalah dengan penggunaan rawatan anoksik dan diikuti dengan rawatan air panas pada suhu 50°C, rawatan udara panas pada suhu 50°C, kawalan dan akhir sekali rawatan udara panas pada suhu 30°C.

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LIST OF ABBREVIATIONS

° C	Degree Celsius
%	Percentage
°F	Fahrenheit
No	Number.
G	gram
Mg	milligram
TBA	Thiobarbituric acid
TCA	Thrichloroacetic acid
CLO_2	Chlorine dioxide

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CHAPTER 1

INTRODUCTION

1.1 Background Of Study

Banana is one of the most consumptable fruit in Malaysia and sometimes bananas especially 'Berangan' (*Musa acuminata*) are exported to overseas. However, there are some problems while exporting this climacteric fruits. Even though banana is kept in low temperature storage, it still show some symptom likes blackening on the surface, surface discoloration, dull or smoky anal color, subepidermal tissues reveal dark-brown streaks, failure to ripen, and, in severe cases, flesh browning. This symptom is called chilling injury. Although the flesh can still be eaten but the peel appearance has spoiled all of it. Chilling injury results from exposing bananas to temperatures below 13°C (56°F) for a few hours to a few days, depending on cultivar, maturity, and temperature. So in this study, postharvest treatment of heat and anoxic were used to prevent the manifestation of chilling injury as well as for disinfestations and disinfection of bananas.

1.2 Problem Statement

Chilling injury is primarily a disorder of crops of tropical and subtropical origin. The minimum safe temperature for chilling sensitive commodities will be well above their freezing point. The critical temperature for chilling injury varies with the commodity, but it generally occurs when produce is stored at temperatures below 10°–13°C. Therefore, crops, which are susceptible to chilling injury often, have a short storage life as low temperatures cannot be used to slow down deterioration and pathogen growth. Chilling injury may occur in the field, in transit or distribution, in retail or home refrigerators. The effects of short periods of chilling may be cumulative in some commodities. Chilling injury will also cause the infected fruits such as 'Berangan' banana to be easily attacked by microorganism and pathogen. Thus, this banana will be damaged because of their tissue breakdown. Although all the precautions have been taken, this problem is still occurring because of the fluctuation of temperature during the storage. Fluctuation of temperature might happen when opening the fridge door, out of electricity, human error and etc. Chilling injury can be seen during the storage and after storage. If chilling injury happened, it might attract other disorders to harm the bananas. Banana that has chilling injury will show an awful cosmetic appearances.

1.3 Significant of Study

Heat treatment is normally used to free the plant materials from pathogen, the temperature and exposure duration having been determined empirically. Postharvest heat treatment of fruit is used for insect disinfestations and disease control, to modify responses to other stresses and maintain fruit quality during storage. Postharvest heat treatment before storage is needed in extending the shelf life and reducing the incidence of chilling injury. Under the optimum storage temperature of 13-14°C (56-58°F) for storage and transport. Chilling injury will appear if temperature fluctuate even 1 to 2 degrees. The postharvest heat and anoxic treatment that were applied in this study, perhaps would help in reducing the chilling injury problem in banana and increase its quality.

1.4 Objective

The objective of this study is to determine the effects of different postharvest heat and anoxic treatments prior to low temperature storage in reducing chilling injury of 'Berangan' banana during cold storage and when held under ambient conditions thereafter.

CHAPTER 2

LITERATURE REVIEW

2.1 Banana

Bananas (*Musa acuminata.*) especially 'Berangan' are everyone's favorite. The 'Berangan' banana is the most widely grown banana cultivar (figure 2.1). Banana had been reported to be a native of Southeast Asia especially Malaysia and Indonesia (Simmonds, 1966; Valmayor *et al*., 1990). 'Berangan' bananas are ubiquitous, cheap and available year-round in fresh form.

Figure 2.1: Immature "Berangan" Banana

Taxonomically, banana comes under the order Zingeberales, of the family Musaceae (Simmonds, 1966; Hulme, 1970) and the edible fruit of gens Musa (Von Loesecke, 1949; Forsyth, 1980; Nakosone and Paull, 1998). The outer skin is partially green when sold in food markets and turns yellow when it ripens. When over-ripe, the skin will turn black and the flesh becomes mushy. Bananas ripen naturally with the abundant existence of natural plant hormone, which is the ethylene and are at their peak ripeness when the peel is all yellow with a few dark brown specks beginning to appear on the skin of the banana.

The banana fruit is a berry. It contains many ovules, but no seed, fruit develops by means of parthenocarphy without fertilization. Banana differs from cultivar to cultivar in characteristics such as shape, size color of skin and flavor (Samson, 1980).

The banana fruit grows in hanging clusters, with up to 20 fruit to a tier (called a hand), and 3–20 tiers to a bunch. The total of the hanging clusters is known as a bunch, or commercially as a "banana stem", and can weigh from 30–50 kg. The fruit averages 125 g, of which approximately 75% is water and 25% dry matter content. Each individual fruit (known as a banana or 'finger') has a protective outer layer (a peel or skin) with a fleshy edible inner portion. Both skin and inner part can be eaten raw or cooked. Western cultures generally eat the inside raw and throw away the skin while some Asian cultures generally eat both the skin and inside if cooked. Typically, the fruit has numerous strings (called 'phloem bundles') which run between the skin and the inner part. Bananas are a valuable source of vitamin B6, vitamin C, and potassium (Marisa M. Wall., 2006).

Bananas were first became widely popular in the 1800s, when railway companies started establishing plantations of Gros Michel or “Big Michael” bananas along their tracks. These bananas could be easily transported once they are ripe, generating double profits for the railway by allowing the company to charge for passengers and freight, and to transport a costly exotic food on the same train. The price of bananas started to drop, and bananas quickly became a very familiar tropical fruit.

Besides high fiber contain, bananas also have high potassium to sodium content that may prevent high blood pressure and its complications. High potassium in banana may also prevent renal calcium loss, in effect preventing bone breakdown. Banana also can contribute electrolyte replacement if diarrhea occurs and increased absorption of nutrients. By having some antacid effect that protects us from peptic ulcers. Pectin content, a hydrocolloid, can ease constipation by normalizing movement through the intestine. The low glycemic index in unripe bananas is of particular benefit to people with diabetes. High fructooligosaccharide content may work as a prebioticc, nourishing the intestinal flora to produce beneficial vitamins and enzymes. Carotenoid content has antioxidant effects, and protects against vitamin A deficiency, resulting in e.g. night blindness (Figure 2.2).

Moderate consumption decreases risk of kidney cancer, possibly due to antioxidant phenolic compounds. In contrast, large consumption of highly processed fruit juice increases the risk of kidney cancer. Hamilton & Jensen (2001) had established that all bananas contain the same number of calories. The study determined that the calorific density varied depending on the size of banana to keep the calorific value at a constant 163 Kcal.

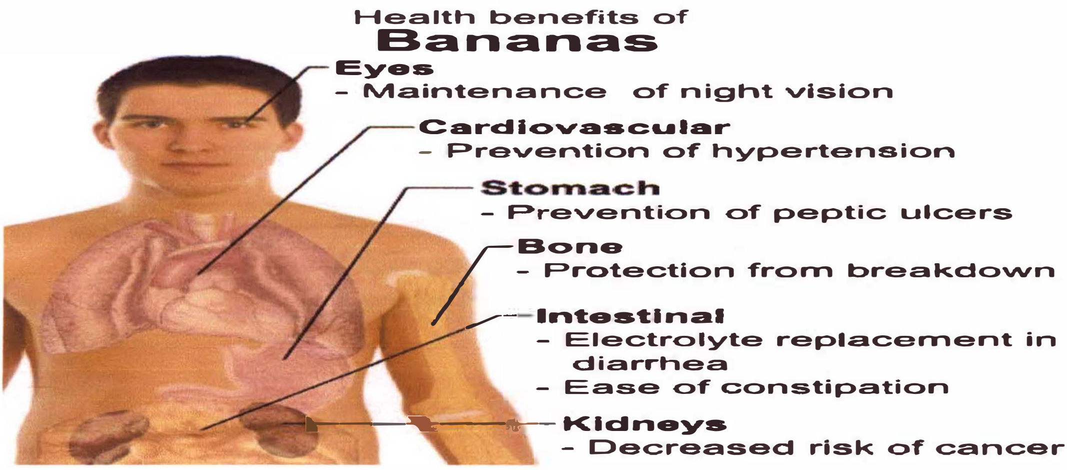

Figure 2.2: The Health Benefit of Banana (Mikael Häggström, 2007)

2.2 Chilling Injury

By lowering the storage temperature, it will decrease not only the respiration and the production of ethylene, but also the rate of response of the tissue to ethylene, so that at lower temperatures longer exposure to a given concentration of ethylene is required to initiate ripening. However, if the temperature is lower than the optimum temperature it will cause chilling injury.

Chilling injury is physiological disorders cause by the cool temperature especially during the storage. Chilling injury results from exposing bananas to temperatures below 13°C (56°F) for a few hours to a few days, depending on cultivar, maturity, and temperature. Chilling injury is a separate phenomenon from freezing injury, which results from the tissue and formation of ice crystal at temperature below the freezing points. Research shows that there are several symptom will be shown by banana when there are infected by this problem such as pitting of the skin, usually due to collapse of the cells beneath the surface, and the pits are often discolored, brown streaking on skin, water loss accentuates the extent of pitting and the development of off flavor or odors (Table 2.1).

Table 2.1: Recommended Minimum Storage Temperature and Potential Chilling Injury Symptoms of Fruits, Vegetables and Floriculture Products (Skog, 2008).

Commodity	Recommended Minimum Storage Temperature (°C)	Potential Chilling Injury Symptoms
Anthurium	> 13	–Darkening and water-soaked appearance
Apple	0–7	–Core or flesh browning, fermented flavour, spongy texture, susceptibility and symptoms vary with cultivar
Asparagus	2–4	–Occurs primarily at the tips - darkened and water-soaked followed by bacterial soft rot
Avocado	7–13	–Darkening of vascular tissues, discolouration of flesh and skin, off-flavours and odours, abnormal ripening
Banana	> 13	–Green fruit: brown under peel discolouration. Ripe fruit: brown to black peel discolouration, off-flavours, abnormal ripening
Basil	7–10	–Wilting, water-soaked appearance, darkening
Bean (snap)	7–10	–Russeting, pitting
Cantaloupe	2–5	–Pitting, surface decay
Cucumber	7–10	–Pitting of surface, lenticel area affected first, followed by Fusarium and other rots
Egg-plant	7–13	–Scald-like browning, pitting, flesh browning, decay and loosening of capstems, Alternaria rot
Grapefruit	10–15	–Brown pitting of rind, watery breakdown of internal and external tissues, fermented odour
Honeydew Melon	7–13	–Water-soaking of the rind, softening, greying or browning, surface becomes soft and sticky resulting in increased decay
Lemon	10–14	–As for grapefruit, plus red blotch
Lime	9–12	–As for grapefruit
Mango	> 13	–Greyish skin discolouration, pitting, uneven ripening, poor flavour,

		increased susceptibility to Alternaria rot
Okra	7–10	–Pitting
Orange	2–5	–As for grapefruit
Orchid, cattleya	7–10	–Discolouration of column first, then sepals and petals
Papaya	7–13	–Pitting, olive or brown discolouration, abnormal ripening
Peach/Nectarine	-0.5–1	(Critical temperature 2–8) – internal breakdown, mealiness, abnormal ripening, flesh browning or reddening
Pepper	7–13	–Water-soaked appearance, sheet pittting, darkening, predisposition to Alternaria and Botrytis
Pineapple	7–13	–Flesh watery, followed by browning or blackening
Poinsettia	> 13	–Leaf drop, wilting
Potato	3–10	–Mahogany browning, sweetening
Pumpkins/winter squash	10–15	–Rot, primarily Alternaria
Sweet potato	> 13	–Flesh discolouration, internal breakdown, increased decay, off-flavours, hard core when cooked
Tomato – ripe – green	7–13 > 13	–Rubbery texture, watery flesh, irregular ripening, seed browning
Watermelon	10–15	–Pitting, loss of flavour, fading of red colour
Zucchini/summer squash	5–10	–Surface pitting, rapid decay

Chilling injury causes the release of metabolites such as amino acids and sugar and mineral salts from cells and together with degradation of cells structure provide an excellent substrate for the growth of pathogenic organism, especially fungi. There are some potential problems that will be shown by the banana such as surface lesion due to pitting or sunken areas and discoloration which occur most frequently in products with a firm, thick peel such as citrus or cucumber. Water-soaking of tissues can also occurs most frequently in fruit and vegetables with thin or soft peels such as peppers, asparagus and grapes. Besides, water loss, dessication, shrivelling, internal discolouration, tissue breakdown, failure of fruit to ripen, or uneven or slow ripening, accelerated senescence, ethylene production, shortened storage or shelf life, compositional changes e.g., flavor and texture, loss of growth or sprouting capability, wilting, increased decay due to leakage of plant metabolites, which encourage growth of micro-organisms, especially fungi can lso be observed (Figure 2.3, 2.4, 2.5).

Figure 2.3: Banana with Chilling Injury Symptoms

Figure 2.4: Banana Peel Becomes Blacken due to Chilling Injury

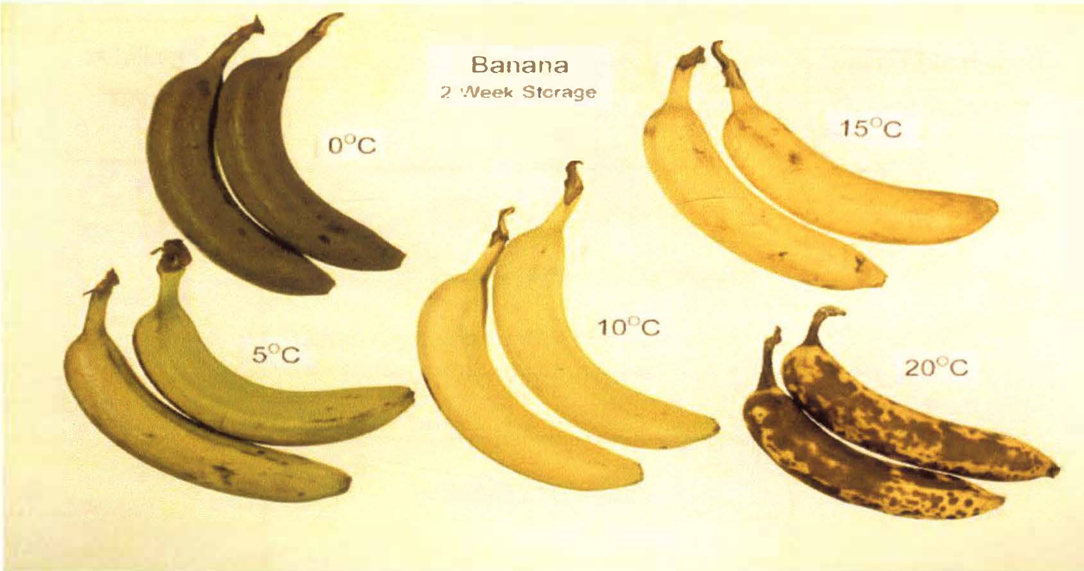

Figure 2.5: The Conditions of Bananas when Stored at Different Storage Temperature.

The mechanism or the development of chilling injury can be divided into two separate events, the primary reversible event and the secondary irreversible events as illustrated in Figure 2.6;

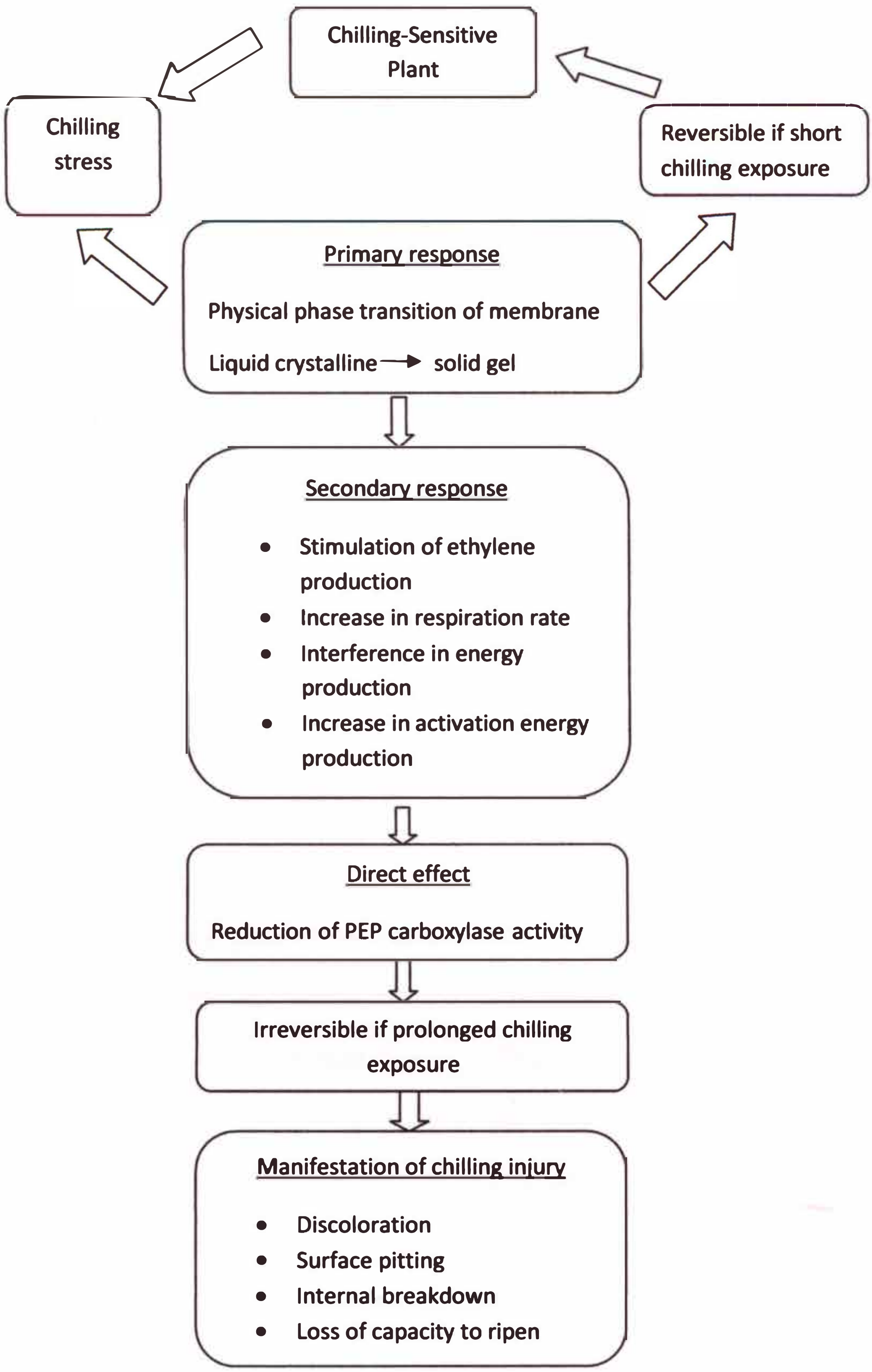

Figure 2.6: Schematic Diagram of the Response of Sensitivity Plants to Chilling Stress (Wang, 1992).

There are several ways that can be adopted during postharvest treatment to avoid the chilling injury problem. Minimize the length of time the crop is exposed to the chilling temperature because when the exposure is minimal, the damage can be reversed and no visual symptoms will occur. Preconditioning of the commodity by stepwise cooling of the commodity can allow the fruit to adapt to the cooler temperatures and minimize chilling injury development. Intermittent warming by warming the commodity to room temperature at intervals during storage before permanent injury has occurred will allow the product to recover and prevent chilling injury symptoms. This treatment may, however, cause undesirable softening and increase decay and may cause condensation to form on the product. Certain cultivars are more resistant to chilling. Proper pre-harvest nutrition can minimize chilling susceptibility. Calcium treatment may stabilize cellular membranes and reduce chilling injury in certain commodities. Maturity and ripeness selection are generally, riper fruit is less susceptible to chilling injury. Ripe tomatoes, bananas and avocados tolerate lower temperatures than unripe fruit. Peaches and nectarines, which are ripened for 1–2 days after harvest prior to storage, are less susceptible to low temperatures. High humidity can minimize desiccation due to chilling injury. Controlled or modified atmospheres (generally O_2 <5%, CO_2 >2%) can slow plant metabolism and slow chilling injury development in certain crops (e.g., peaches, nectarines, okra, avocado). Controlled atmospheres can also allow longer storage of chilling sensitive crops when stored above their critical temperature. Controlled atmospheres may in some cases further stress crops and increase chilling injury susceptibility (e.g., some apple cultivars, cucumbers, tomatoes, asparagus and citrus). Other methods, which are still in experimental stages, include treatment with hormones or other chemicals to stabilize plant membranes and induction of chilling resistance by exposure to other stresses such as high temperature or low oxygen concentration.

Table 2.2: The Recommended Storage Condition for Optimum Ripening of Some Cultivars of Bananas

Variation	Temperature
All cultivar of banana	12-21.5 °C (Peacock and Blake,1970)
All cultivars of banana	10 – 12 °C (Wilkinson,1970)
Most Philipine banana	13 °C (Pantastico and Mendoza, 1970)
'Embun and 'Rastali'	20 °C (Broughton and Wu, 1979)
Cavendish	13 °C (Pantastico,1980)
Tetraploid dessert clones (AAAA group)	12 – 14 °C (Marriot and New, 1975)

2.3 Postharvest Treatments for Chilling Injury

Postharvest heat treatment is being used for disinfestations and disinfection of an increasing variety of crops including 'Berangan' banana. By exposing fruits especially banana to high temperature forced or static air. It can decrease fungal infections. Research also shows that the inhibition of ripening by heat may be mediated by its effect on the ripening hormone.

During the heating, not only is endogenous ethylene production inhibited, but fruits will not respond to exogenous ethylene (Seymour *et al.*, 1987; Young *et al.*, 1990). This indicates either a loss or inactivation of ethylene receptors, or the inability to transfer the signal trough the subsequent series of events leading to ripening (Lurie 1998). Research shown that the expression of tomato ripening genes is inhibited by high temperature (Picton and Grieson, 1988). Heat treatment can also be used to inhibit ripening processes or to induce skin damage during storage, thus extending storability and marketing (Woolf, 1997; Lurie, 1998; Paull and Chen, 2000).

2.3.1.1 Hot Water Treatment

The beneficial effect of pre-storage hot water immersion treatment (HWT) to prevent rot development has been shown in numerous temperate, sub tropical and tropical fruits, vegetables and flowers (Hara *et al.*, 1996; Lurie, 1998; Schirra *et al.*, 2000). Hot water was originally used for fungal control, but has extended to disinfestations of insects (Lurie 1998). Hot water can be applied by placing 'Berangan' banana in boil water. By applying hot air before storage hopefully, it will decrease the chilling injury on banana. Hot water treatment was firstly reported in 1992 to control decay on citrus fruits (Fawcett, 1922) but their use has been extended to insect disinfestations (Lurie, 1998).

2.3.1.2 Hot Air Treatment

Hot air can be applied by placing fruits in a heated chamber with a ventilating fan or by applying forced hot air. Heating without forced air can reduce decay caused by *Botrytis cinera* and *Penicillium expansum* in apple fruit (Fallik *et al.*, 1996c; Klein *et al.*, 1997b) and *Botrytis cinera* in tomatoes (Fallik *et al.*, 1993) Hot air treatment of 35–40°C inhibits ethylene synthesis within hours in both apples and tomatoes (Biggs *et al.*, 1988; Klein 1989). Elovated temperatures of 35–38°C can cause endogenous ACC to accumulate in apple and tomato tissue concomitantly with the decrease in ethylene (Yu *et al.*, 1980 ; Atta Aly , 1992), though raising the temperature higher or holding the fruits longer at the raised temperature will cause the disappearance of ACC as well (Klein,1989 ; Atta Aly,1992).

2.3.1.3 Anoxic Treatment

Anoxic treatment is a treatment involving flushing the enclosure air by applying inert gas such as N_2, Argon and Helium separately or in combination for a selected period. An anoxic treatment would eliminate organism such as insect, fungi and microbes in the enclosure placed around the object. Thus, application is practiced commercially in postharvest and food industry.

Anoxic treatment is a treatment to maintain a high level of firmness at low temperature and reduced the decrease in the firmness during the shelf life by using pure N_2. Furthermore, the treatment reduced in the increases in membrane permeability and lipid peroxidation, delayed the increases in both O_2 production rate and H_2O_2 content, increased activities of superoxide dismutase (SOD) and peroxidase (POD) but reduced lipoxygenase (LOX) activity throughout storage period (Song *et al.*, 2009).

Fruit exposed to N_2 gas exhibited higher concentrations of ATP, ADP and AMP and adenylate energy charge levels, and lower levels of browning index and membrane permeability, compared to control (non-N_2-treated) fruit. Greater differences in ATP and ADP concentrations and adenylate energy charge levels of pericarp tissues between N_2-treated and control fruit were more manifest after 4 and 6 days of storage, in association with significant differences at the 5% level in the pericarp browning index. It is suggested that pre-storage anoxia treatment maintains membrane integrity of pericarp tissues, with high ATP and ADP concentrations and high adenylate energy charge levels. Thus, the loss of cellular compartmentalization (mixing of enzymes and substrates) that leads to enzymatic browning of litchi fruit pericarp is delayed (Hai *et al.*, 2007).

2.4 Other Treatments

'Berangan' bananas were washed using chlorine dioxide solution (5 mg/L) to sanitize the fruits and ensure they were free from any fungi and bacteria prior to heat and anoxic treatments.

CHAPTER 3

MATERIALS AND METHODS

3.1 Fruits Source and Preparation

Banana (*Musa acuminata*, AAA group cv. 'Berangan') used in this study were purchased from local fruit market in Kuala Terengganu, Terengganu. All the banana used were at index 2 in maturity (Figure 3.1). Only bananas from 2^{nd,} 3rd, and 4th hands were used in the experiment following suggestion from Mustaffa (1997) in which he found that there were no significant difference in physico-chemical characteristics of bananas 'Montel' from 2^{nd,} 3rd, and 4th hands. The bananas were de-fingered and 15 bananas were allocated for every treatment. All the bananas were places in boxes and stored at 13±1°C in cold room for 3 weeks and taken out from the cold storage and place at ambient temperature for another week.

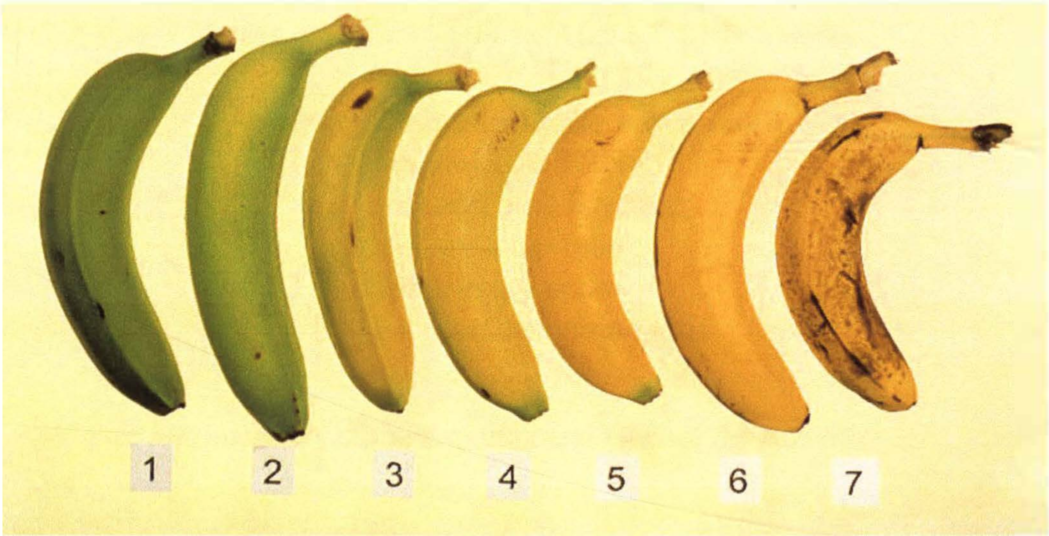

Figure 3.1: Banana Maturity Index Chart

Three bananas from each treatment were sampled out from the storage at weekly intervals for analysis. Once the banana have been obtained , the bananas were dehanded and defingered using knife. After all the bananas were ready, all of them were washed using tap water and dipped in the anti microbial agent, which was the chlorine dioxide. The chlorine dioxide was diluted 5 mg in 1 liter of distilled water for 3 minutes. Then the bananas were removed from the solution and placed in a container to the ambient temperature to air dried them in order to make sure there is no excessive solution on the skin of banana. The summarized experimental flow activities are shown in the Figure 3.2 below and the parameters analyzed are peel and pulp colour, peel and pulp firmness, peel and pulp ratio, chilling injury score and TBA reactive compounds.

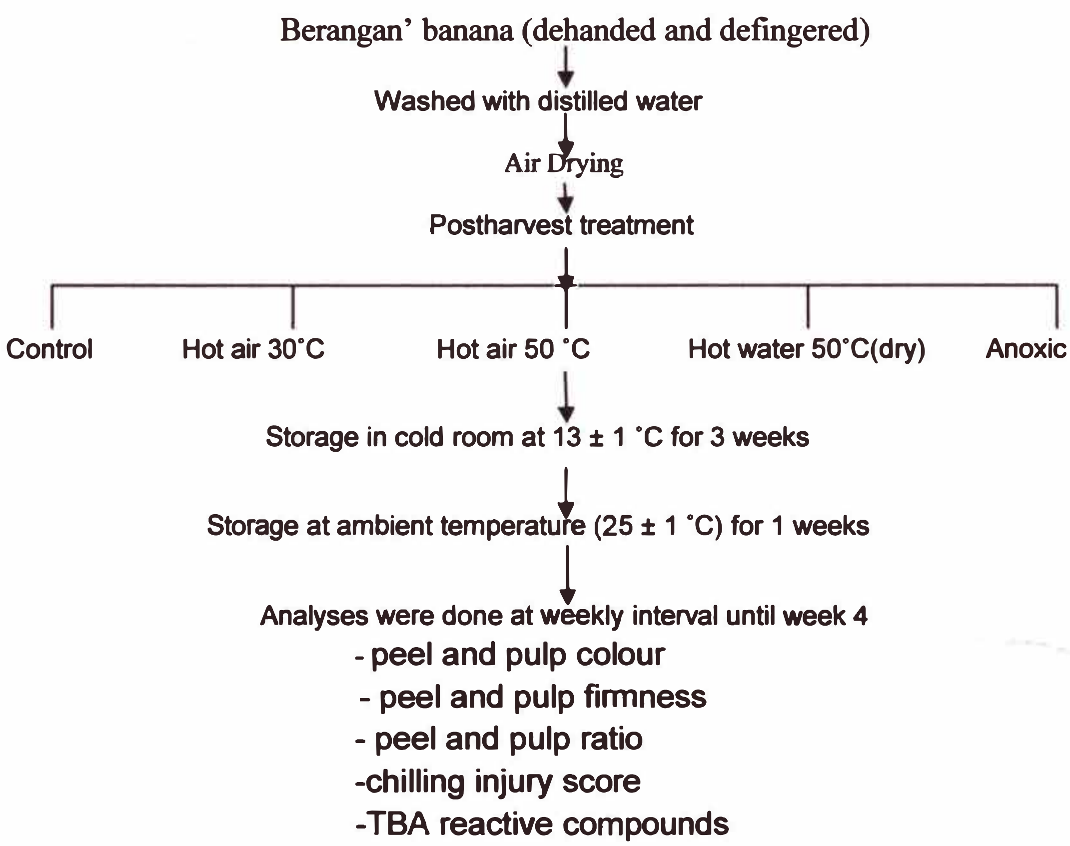

Figure 3.2: Summary of the Experimental Flow of the Activities.

3.2 Chemicals

Chlorine dioxide (ClO_2) used were food grade to make sure it is safe for consumption. Meanwhile, Thiobarbaturic acid (TBA) and Trichloroacetic acid (TCA) were used for analysis grade. Nitrogen gas was obtained from nitrogen generator (Domnick Hunter).

3.3 Postharvest Treatment

After being washed and with chlorine dioxide (5mg/L), the fruits were subjected to different treatments. This study comprised of 4 treatments and bananas without any treatment served as control. Each treatment consisted of 15 fingers of bananas.

3.3.1 Hot Water (50°C) Treatment

The bananas were immersed into 50°C hot water for 2 minutes. The samples were then dried with a clean cloth/tissue paper. Before stored in a cold room at temperature 13±1°C for 3 weeks. Three bananas were taken out every week for analyses. After 3 weeks, the bananas were then stored at ambient temperature and evaluated after 1 week.

3.3.2 Hot Air (30°C) Treatment

The bananas were placed in an oven at 30°C for 3 hours. Then, the banana were then stored in a cold room at temperature 13±1°C for 3 weeks. Three fingers of banana were taken out every week for analyses. After 3 weeks, the bananas were then stored at ambient temperature and evaluated after 1 week.

3.3.3 Hot Air (50˚C) Treatment

The bananas were placed in an oven at 50˚C for 3 hours. Then, the banana were taken out and stored in a cold room at temperature 13±1˚C for 3 weeks. Three fingers of banana were taken out every week for analyses. After 3 weeks, the bananas were then stored at ambient temperature and evaluated after 1 week.

3.3.4 Anoxic Treatment

The 'Berangan' bananas were placed in a rectangular air-tight container and flush with nitrogen gas for 6 hours. Then, the samples were stored in a cold room at temperature 13 ± 1 ˚C for 3 weeks. Three fingers of banana were taken out every week for analyses. After 3 weeks, the bananas were then stored at ambient temperature and evaluated after 1 week.

3.4. Physico–chemical Analysis

3.4.1 Chilling Injury Score

Chilling injury score was done based on the study by Promyou *et al* (2008). The percentage of the chilling injury on the peel was observed at weekly intervals based on scales below;

Score	Symtoms
1	No chilling injury
2	Mild injury (1 – 20 % of fruits affected)
3	Moderate injury (21 - 50 % of fruits affected)
4	Severe injury (51 - 80 % of fruits affected)
5	Very severe injury (81 - 100 % of fruits affected)

3.4.2 Peel: Pulp Ratio

The bananas were deskinned. The peel and pulp were weighed using digital balance at 2 decimal points and the values were recorded. This analysis was carried out every week until week 4.

3.4.3 Peel and Pulp Texture

The changes of banana's peel and pulp texture were analyzed by using Texture Analyzer TA.XTplus by using the P2N probe (needle). These analyses were carried out every week until week 4. The peel and pulp firmness were determine by the highest positive peaks obtained from the texture profile curves. The testing parameters used are follows:

Pre test speed	: 1.00
Test speed	: 0.50
Post test speed	: 5.00

Target mode : 10 mm (distance)

Trigger mode : 5.0 g

3.4.4 Peel and Pulp Colour

The changes in banana's peel and pulp colour were determined by using Chromameter Minolta Lab (Model Cr 200 Trimulus Colour Analyses). The value of L*,a* and b* values were taken at 3 different positions on each banana. The L*, a* and b* values obtained were then used to calculate the total colour change (ΔC) of peel and pulp using the equation below;

$$\Delta C = \sqrt{((L_n - L_0)^2 + (a_n - a_0)^2 + (b_n - b_0)^2)}$$

3.4.5 TBA Value

TBA (thiobarbaturic acid) method was done usually to measure malondialdehyde (MDA), the main product of lipid peroxidation. This peroxidation process can be mediated by enzymes such as lipoxygenase (LOX; Berger et al., 2001). Five grams of banana peel was homogenized with 25 mL of 5% (w/v) trichloroacetic acid (TCA). The mixture was centrifuged for 10 min at 4000 ×*g*. Thiobarbituric acid (TBA) reactivity was determined by adding 2.5 mL of 0.5% TBA in 15% TCA to 1.5 mL of the supernatant.

The reaction solution was held for 20 min in a boiling water bath, then cooled quickly and finally centrifuged at 12,000 ×*g* for 10 min to clarify the solution for a better reading later with the spectrophotometer. Absorbance was measured at 532 nm and corrected for non-specific turbidity by subtracting the absorbance at 600 nm, calculated with an extinction coefficient of 1.55 $nmolL^{-1}m^{-1}$ and expressed as nmol g^{-1} FW. (Promyou *et al.*, 2008)

3.4.6 Experimental Design and Statistical Analysis

The experimental are based on completely randomized block design with one treatment factor – heat and anoxic treatment (ABCDE). Below is the detail of the sample replication;

Treatment / Parameter	Control	Hot water 50°C	Hot air 30°C	Hot air 50°C	Anoxic
Colour	$3X^3$	$3X^3$	$3X^3$	$3X^3$	$3X^3$
Texture	$3X^3$	$3X^3$	$3X^3$	$3X^3$	$3X^3$
Peel and Pulp	3X	3X	3X	3X	3X
Chiling injury score	3X	3X	3X	3X	3X
TBA	3X	3X	3X	3X	3X

Represent; X = one fruit / replicate; X^3 = 3 readings / fruit

All the data were analyzed using one way Anova and the significant difference between the treatments at ($P \leq 0.05$) will be determined using Tukey Test. The statistical program used was the SPSS program.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Chilling Injury Score

Chilling injury is a common physiological disorder that can be detected in most fruits and vegetables which are stored at lower temperature than its critical temperature. For a clear chilling injury observation, a score had been made to clearly define the degree or level of the chilling injury. The chilling injury scores of the treated bananas starting from week 0 to week 4 were presented in Figure 4.1.

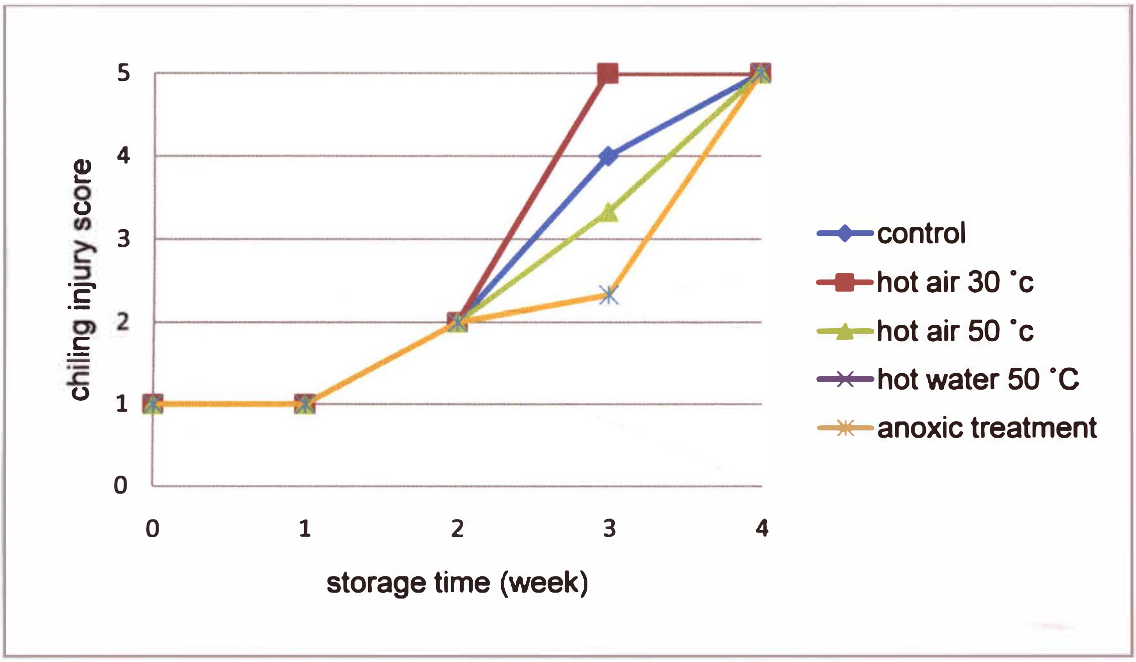

Figure 4.1: Chilling injury scores of bananas treated with different postharvest treatments during storage.

From the above figure, the chilling injury scores of each treatment were the same after 1 week of storage. On the second week, the chilling injury scores of all the treatments increasing to scale 2. This result was supported by the statistical analysis which showed that all the treatments were not significantly different on week 0 until week 2 of storage (Table 4.1). The differences of the chilling injury infection to all the samples were not clearly identified. The symptoms occurred clearly on week 3, where all the treatments had different score of chilling injury. Hot air 30°C, was the highest rating on week 3 which was at score 5. Chilling injury is thought to stem from the inability of cell membranes to function properly at lower storage temperatures due to a phase transition in the membrane lipid (Aggarwall, 2001).

Anoxic treatment showed the least score on week 3, which was at scale 2. This result was strongly supported by statistical analysis that stated that both treatments were significantly different ($p<0.05$) on week 3. Short-term anoxic treatment was a mean to eliminate the oxygen and replaced it with nitrogen gas for 6 hours and this method was believed to reduce the increases in membrane permeability and lipid peroxidation, delayed the increases in both oxygen production rate and hydrogen peroxide content, increase activities of superoxide dismutase and peroxidase but reduce lipoxygenase activities throughout storage period. The anoxic treatment can also inhibit ethylene production which will cause ripening in climacteric fruits especially in banana. However, on the last week of storage, all the treated bananas showed the same score of chilling injury symptoms which showed in Table 3.1 that all the treatments were not significantly different on the last week of storage. Chilling injury symptoms that were observed on the last week of storage were varied in terms of the physical characteristics. The localized injury to the epidermal and sub epidermal cells ultimately caused the cells to collapse and form a pit in the banana surface. This injury impaired the normal development of the crystalline wax structure and increase water permeability in the injured region.

Table 4.1: Effects of Postharvest Heat and Anoxic Treatment on Chilling Injury Score of Banana

Treatment	Week 0	Week 1	Week 2	Week 3	Week 4
Control	1.00 ± 0.00^{Aa}	1.00 ± 0.00^{Aa}	2.00 ± 0.00^{Aa}	4.00 ± 0.00^{Ab}	$5.00 \pm 0.00^{A\,a}$
Hot air 30°C	1.00 ± 0.00^{Aa}	1.00 ± 0.00^{Aa}	2.00 ± 0.00^{Aa}	5.00 ± 0.00^{Ac}	5.00 ± 0.00^{Aa}
Hot air 50°C	1.00 ± 0.00^{Aa}	1.00 ± 0.00^{Aa}	2.00 ± 0.00^{Aa}	3.00 ± 0.00^{Aa}	5.00 ± 0.00^{Aa}
Hot water 50°C	1.00 ± 0.00^{Aa}	1.00 ± 0.00^{Aa}	2.00 ± 0.00^{Ba}	2.30 ± 5.77^{Ba}	5.00 ± 0.00^{Ca}
Anoxic treatment	1.00 ± 0.00^{Aa}	1.00 ± 0.00^{Aa}	2.00 ± 0.00^{Aa}	2.30 ± 5.77^{Aa}	5.00 ± 0.00^{Aa}

Note : Values in Table 4.1 are mean of 3 replicates. Mean (n=3) ± standard deviation.

A – C : Means bearing the same superscript within the same row are not significantly different at 5 % level ($p < 0.05$).

a – b : Means bearing the same superscript within the same column are not significantly different at 5 % level ($p < 0.05$).

4.2 Peel to Pulp Weight Ratio

The rate and extend of deterioration in fresh fruit including banana is very dependent on the intrinsic state of the tissue. Degradation of membrane cell in banana peel occurs due to chilling injury. Surface lesion, pitting, large sunken area, this discoloration and water soaking of the tissue are the example of chilling injury symptoms that can be found on banana's peel. For pulp, there are no huge effects that can be caused by chilling injury as chilling manifestation only occurs on the peel of fruits. The peel to pulp weight ratios were showed in Figure 4.2 below.

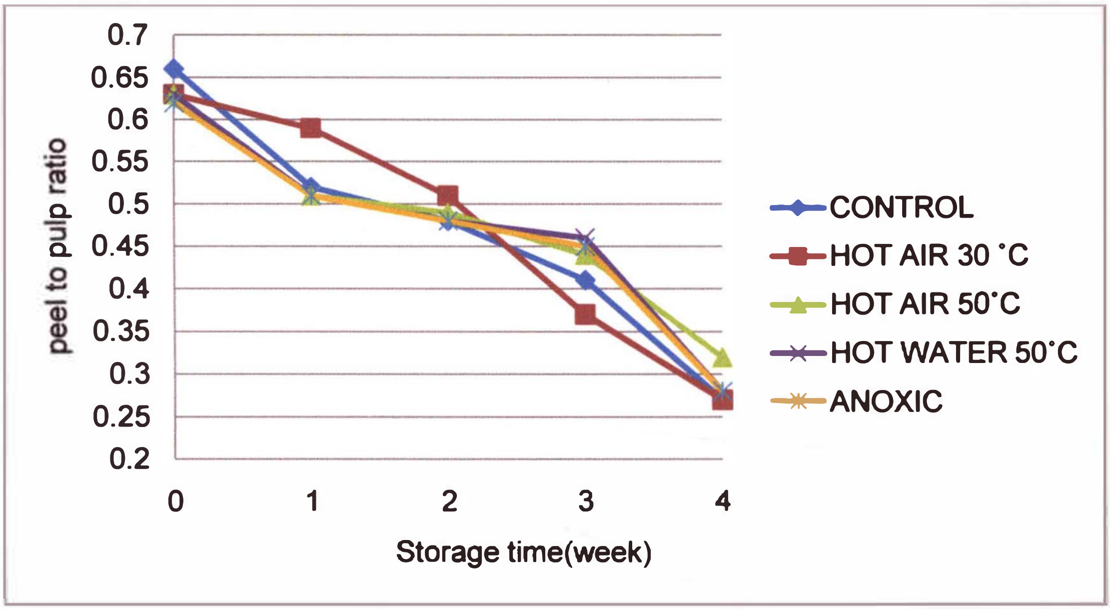

Figure 4.2: Peel to Pulp Weight Ratio of Bananas Treated with Different Postharvest Treatments during Storage

From Figure 4.2 above, the trend of the peel to pulp ratio was decreasing over the storage time. The ratios of all the treatments from week 0 to week 4 were not significantly different ($p>0.05$) among each other except during week 3, where there were some changes in the peel to pulp ratio. Treatments with anoxic, hot water (50°C) and hot air (50°C) were not significantly different on week 3. However, these three treatments were significantly different if compared to control and hot air (30°C) treatments as shown in Table 4.2. The reducing ratio over the storage time was due to the water loss and surface degradation of the infected bananas peel with chilling injury manifestation. The storage temperature of 13°C caused some evaporation of moisture through the infected pits or pores on the bananas peel surface into the cold room atmosphere. The declining of peel weight was greater than the declining of pulp weight, as the pulp was not infected by the chilling injury symptoms. Temperature has a profound effect on the postharvest quality of harvested fresh produces. Perkins–Veazie and Collins (1999) found that transferring blackberry fruit to 20°C for 2 days after low temperature storage intervals was detrimental to fruit quality, resulting in weight loss, leakage, decay, and softening in 'Navaho' and 'Shawnee' blueberry cultivars. The loss in water is dependent on the fruits cultivars. In general, freshly harvested produce is held under reduced temperature to minimize respiration and weight loss.

The reduction in temperature should just be above the produce's freezing point temperature or just above its chilling threshold temperature in the case of chilling-sensitive produce. Lowering the temperature of fresh produce lowers its rate of deterioration and thus maintained quality and extends shelf life.

Table 4.2 : Effects of Postharvest Heat and Anoxic Treatments on Peel to Pulp Weight Ratio of Banana

Treatment	Day 0	Week 1	Week 2	Week 3	Week 4
Control	0.68 ± 0.14^{Ca}	0.51 ± 0.01^{BCa}	0.48 ± 0.02^{Ba}	0.41 ± 0.02^{ABab}	0.27 ± 0.01^{Aa}
Hot air 30°C	0.60 ± 0.02^{Da}	0.60 ± 0.04^{Db}	0.51 ± 0.04^{Ca}	0.38 ± 0.01^{Ba}	0.27 ± 0.02^{Aa}
Hot air 50°C	0.54 ± 0.01^{Ba}	0.51 ± 0.01^{Ba}	0.48 ± 0.03^{Ba}	0.44 ± 0.02^{Bb}	0.33 ± 0.08^{Aa}
Hot water 50°C	0.56 ± 0.03^{Ca}	0.51 ± 0.02^{BCa}	0.48 ± 0.01^{Ba}	0.46 ± 0.02^{Bb}	0.28 ± 0.03^{Aa}
Anoxic treatment	0.51 ± 0.04^{BCa}	0.51 ± 0.02^{Ca}	0.48 ± 0.01^{BCa}	0.46 ± 0.02^{Bb}	0.28 ± 0.01^{Aa}

Note : Values in Table 4.2 are mean of 3 replicates. Mean (n=3) ± standard deviation.

A – D : Means bearing the same superscript within the same row are not significantly different at 5 % level ($p < 0.05$).

a – b : Means bearing the same superscript within the same column are not significantly different at 5 % level ($p < 0.05$).

4.3 Peel and Pulp Firmness

Chilling injury can seriously affected the peel and also pulp to some extent in fruits including banana. Peel and pulp will become less firm due to chilling injury during and after storage. The symptoms such as peel blackening, pitting and softening will appear at the banana's peel when chilling injury happened. High water loss may occur, which accentuates the extent of pitting. There was not much symptom that can be seen on the pulp except the pulp will be less firm and browning. Browning often first appears around the vascular (transport) strands in fruit, probably as a result of the action of the enzyme polyphenol oxidase on phenolic compounds released from the vacuole after chilling. The firmness was decreased due to chilling injury during and after storage at 13°C as shown in Figure 4.3.

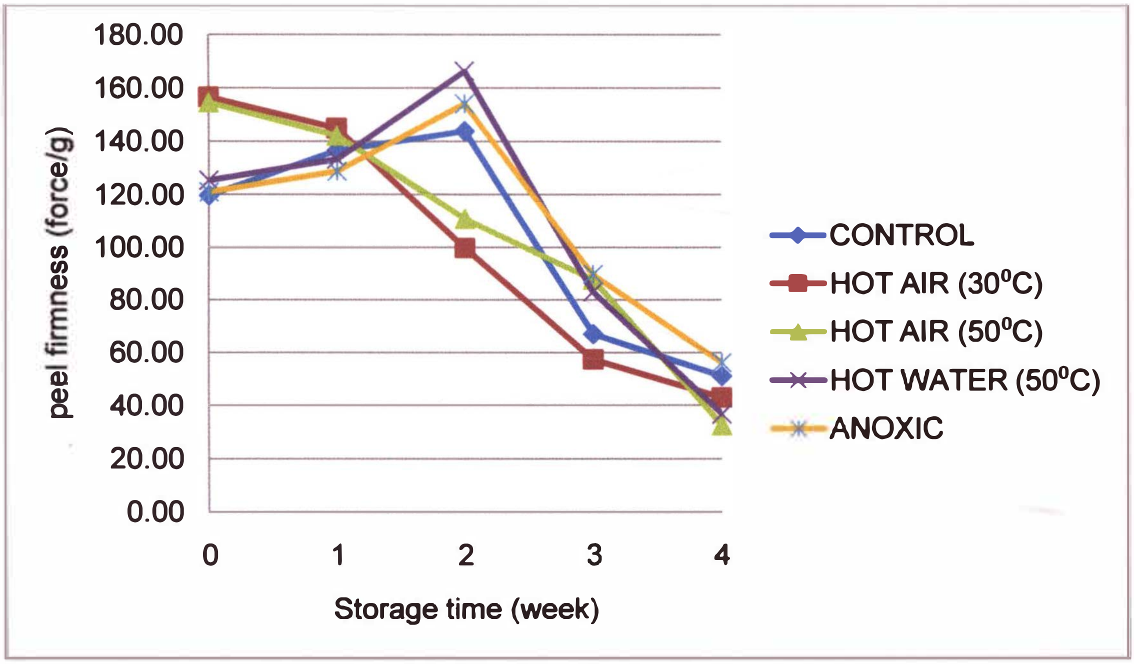

Figure 4.3: Peel firmness of bananas treated with different postharvest treatments during storage.

As can be observed in Figure 4.3, the firmness trends are decreasing along the storage time. However, for control, hot water (50°C) and anoxic treatments there were some increasing in the first 2 weeks. Even though there was no significant different ($p>0.05$) among all the treatment on the first two week. This indicating that all the treatments had the same range of peel firmness. The changes on the peel firmness started to appear on week 3. Hot water (50°C) and anoxic treatment were significantly firmer as compared to control, and hot air (30°C) while treatment with hot air (50°C) gave the least firmness as shown on Table 4.3. This was due to the banana peel of anoxic treatment mentioned before was evaporated due to moisture loss during exposing the banana to the nitrogen for 6 hours. The data showed the normal reading on the week 3 and week 4. However peel firmness for week 4 are not significantly different among all the treatments. For both hot air (30°C) and hot air (50°C), the data show the decreasing from the first week until the fourth week. This tells us that hot air treatment is not suitable for the banana especially on to prolong the quality on its peel. The best treatment based on the peel firmness was anoxic treatment because the treatment gave the highest value.

Table 4.3 : Effects of Postharvest Heat and Anoxic Treatment on Peel Firmness of Banana

Treatment	**Day 0**	**Week 1**	**Week 2**	**Week 3**	**Week 4**
Control	$1.19E2 \pm 3.37^{Ba}$	$1.37E2 \pm 4.75^{Ba}$	$1.44E2 \pm 35.31^{Ba}$	$6.70E1 \pm 12.61^{Aab}$	$5.11E1 \pm 10.11^{Aa}$
Hot air (30°C)	$1.57E2 \pm 33.84^{Ca}$	$1.42E2 \pm 1.42^{BCa}$	$1.66E2 \pm 43.28^{Ca}$	$8.31E1 \pm 9.03^{ABab}$	$4.30E1 \pm 6.39^{Aa}$
Hot air (50°C)	$1.54E2 \pm 46.54^{Aa}$	$1.45E2 \pm 5.62^{Ca}$	$9.98E2 \pm 27.71^{BCa}$	$5.74E1 \pm 8.88^{ABa}$	$3.26E1 \pm 3.70^{Aa}$
Hot water (50°C)	$1.25E2 \pm 10.58^{Ba}$	$1.33E2 \pm 11.36^{Ba}$	$1.11E2 \pm 35.71^{Ba}$	$8.77E1 \pm 12.44^{Bb}$	$3.68E1 \pm 7.43^{Aa}$
Anoxic treatment	$1.21E2 \pm 20.10^{Da}$	$1.28E2 \pm 12.88^{CDa}$	$1.54E2 \pm 26.40^{Ca}$	$8.98E1 \pm 11.78^{Bb}$	$5.62E1 \pm 19.19^{Aa}$

Note : Values in Table 4.3 are mean of 3 replicates. Mean (n=3) ± standard deviation.

A – D : Means bearing the same superscript within the same row are not significantly different at 5 % level ($p<0.05$).

a – b : Means bearing the same superscript within the same column are not significantly different at 5 % level ($p<0.05$).

For the banana's pulp, Figure 4.4 showed a decline pattern for all the treatments where anoxic treatment still gave the best effect as it showed the firmest value until the last week of storage. Statistically all the treatments were not significantly different from week 0 to week 4. But some changes occurred on the third week of storage. Anoxic treatment showed significantly higher value compared to the other treatments. This indicated that banana's pulp which treated with anoxic has highest firmness. On the last week of storage there was no significant different ($p>0.05$) in term of pulp firmness among all the treatments as showed in Table 4.4. The chilling injury can result in the cell wall degradation that make the banana's peel became softer. From the observation and statistical analysis done, the firmness on both pulp and peel were exhibited decreasing patterns throughout the storage mainly on week 3.

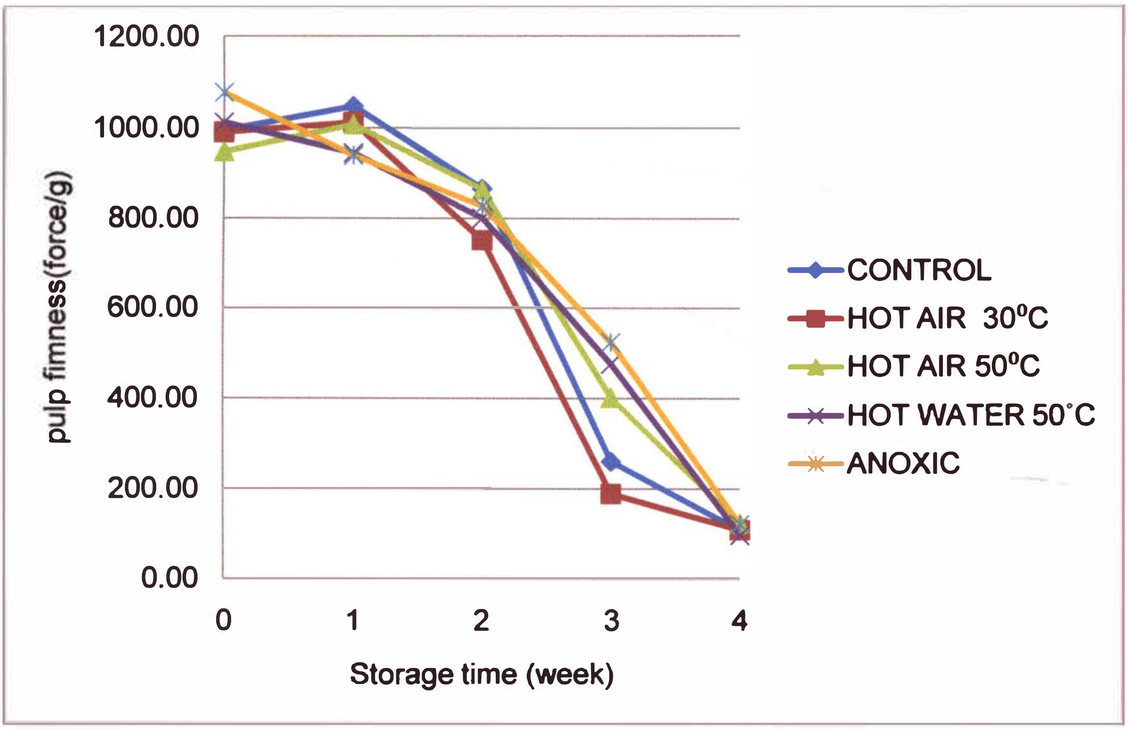

Figure 4.4: Pulp Firmness of Bananas Treated with Different Postharvest Treatments During Storage.

Table 4.4: Effects of Postharvest Heat and Anoxic Treatment on Pulp Firmness of Banana

Treatment	Day 0	Week 1	Week 2	Week 3	Week 4
Control	9.95E2±35.51^{Da}	1.05E2±23.36 ^{Da}	8.67E2±58.86^{Ca}	2.61E2±64.74^{Bab}	1.09E2±19.98^{Aa}
Hot air (30°C)	9.91E2±41.06^{Ca}	1.01E2±80.49^{Ca}	8.01E2±40.30^{Ca}	4.76E2±190.69^{Bab}	1.10E2±29.27^{Aa}
Hot air (50°C)	9.48E2±80.09^{Ca}	1.01E2±49.37^{Ca}	7.53E2±115.49^{Ba}	1.90E2±9.27^{Aa}	1.24E2±13.94^{Aa}
Hot water (50°C)	1.01E2±54.33^{Ca}	9.45E2±113.43^{Ca}	8.65E2±11.74^{Ca}	4.02E2±69.99^{Bab}	98.69E2±14.23^{Aa}
Anoxic treatment	1.08E2±9.19^{Da}	9.40E2±31.83^{CDa}	8.28E2±39.14^{Ca}	5.24E2±124.40^{Bb}	1.24E2±4.33^{Aa}

Note : Values in Table 4.4 are mean of 3 replicates. Mean (n=3) ± standard deviation.

A – D: Means bearing the same superscript within the same row are not significantly different at 5 % level ($p<0.05$).

a – b: Means bearing the same superscript within the same column are not significantly different at 5 % level ($p<0.05$).

4.4 Total Colour Change

Total color change is the total changes of L* a* and b* values calculated as in section 3. The reading was been taken on the banana peel as the peel was blacken and dull during and after storage. Data also been taken on the pulp but not much changes happened on that place. As we know, chilling injury will cause the alteration on the peel. The significant different in terms of total color change cannot be analyzed due to destructive method of sampling. Total color change on the peel as in Figure 12:

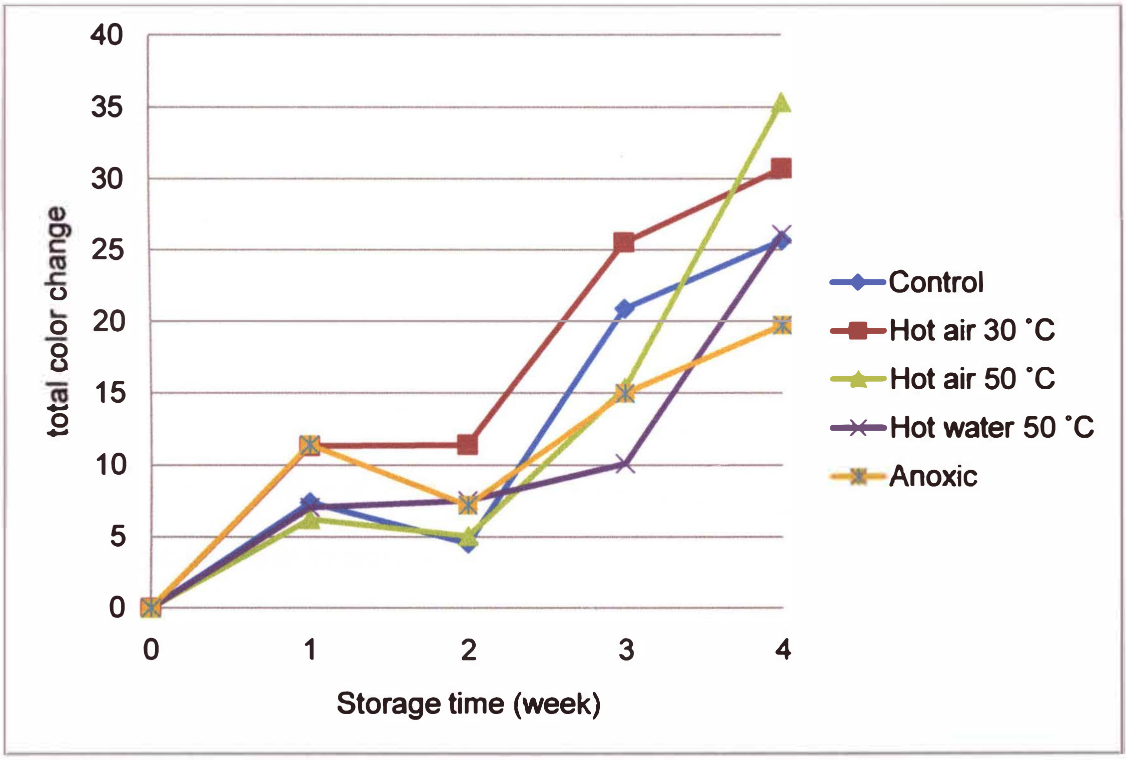

Figure 4.5: Total Color Change of Bananas Peel Treated with Different Postharvest Treatments During Storage.

This figure shows that the total color changes during the storage time of banana's peel. We can see that, all the treatments undergo total color changes simultaneously. At week 2, there are some declining on the graph because of the sample are different from the first week as showed on Table 4.5, 4.6 and 4.7.

The inconsistency might due to the method of sampling even though bananas are harvested from same place and same time but there are still variables among them. The samples on week 2 undergo less total color changes if compared to samples on week 1. From week 0 until week 3, hot air 30°C showed the greatest total color changes if compared to the other treatments. By the way, on the last week of storage hot air 50°C showed the highest changes in peel color. The total color change as calculated according to L*, a* and b* value. According to Tukey test, there is no significant different of L* value among all the treatments starting from week 0 to week 4. Value of a* at the bananas peel are not significantly different on week 0, 1, 2, and 4. Some changes of a* value were detected on week 3. Hot air 30°C was significantly different if compared to the other treatments. The value of b* on the banana's peel are not significantly different on week 0, 1 and 3. However some changes of b* value can be detected on week 2 and 4. Hot air 30°C was significantly different than the other treatments on week 3. This indicating that hot air 30°C undergo highest changes in b* value. On week 4, hot water 50°C was significantly different than the other treatments.

Table 4.5: Effect of Postharvest Heat and Anoxic Treatments on the L* Value on the Peel of Banana

Treatment	Week 0	Week 1	Week 2	Week 3	Week 4
Control	$54.62 \pm 2.29^{Aa*}$	47.86 ± 5.21^{Aa}	56.50 ± 1.03^{Aa}	53.43 ± 4.46^{Aa}	52.57 ± 6.68^{Aa}
Hot air 30°C	55.73 ± 2.58^{Aa}	50.69 ± 1.36^{Aa}	51.79 ± 7.32^{Aa}	56.81 ± 3.36^{Aa}	54.59 ± 2.6^{Aa}
Hot air 50°C	54.23 ± 2.21^{Aa}	48.90 ± 2.90^{Aa}	57.51 ± 1.83^{Aa}	51.94 ± 5.77^{Aa}	49.16 ± 5.06^{Aa}
Hot water 50°C	55.33 ± 3.53^{Aa}	48.64 ± 1.13^{Aa}	52.09 ± 2.25^{Aa}	56.02 ± 1.68^{Aa}	56.99 ± 5.21^{Aa}
Anoxic treatment	55.89 ± 0.75^{Aa}	47.74 ± 5.69^{Aa}	51.28 ± 1.52^{Aa}	55.55 ± 4.02^{Aa}	54.25 ± 3.22^{Aa}

Note: Values in Table 4.5 are mean of 3 replicates. Mean (n=3) ± standard deviation.

A – B: Means bearing the same superscript within the same row are not significantly different at 5 % level ($p<0.05$).

a – b: Means bearing the same superscript within the same column are not significantly different at 5 % level ($p<0.05$).

Table 4.6: Effect of Postharvest Heat and Anoxic Treatments on the A* Value on the Peel of Banana

Treatment	Week 0	Week 1	Week 2	Week 3	Week 4
Control	-17.25 ± 0.60^{Aa}	-13.32 ± 3.41^{Aa}	-17.79 ± 0.77^{Aa}	1.64 ± 2.95^{Bbc}	7.04 ± 0.94^{Ca}
Hot air 30°C	-17.53 ± 0.33^{Aa}	-15.00 ± 1.00^{Aa}	-17.54 ± 0.77^{Aa}	3.90 ± 0.47^{Bc}	7.17 ± 1.27^{Ca}
Hot air 50°C	-16.60 ± 0.94^{Aa}	-16.32 ± 0.63^{Aa}	-16.85 ± 0.52^{Aa}	-4.16 ± 3.23^{Bab}	7.10 ± 2.21^{Ca}
Hot water 50°C	-17.52 ± 0.23^{Aa}	-11.94 ± 3.82^{Aa}	-17.51 ± 0.42^{Ba}	-7.84 ± 0.39^{Ba}	8.18 ± 1.59^{Ca}
Anoxic treatment	-17.52 ± 0.09^{Aa}	-12.78 ± 4.98^{Aa}	-17.07 ± 1.11^{Aa}	-5.00 ± 2.38^{Ba}	6.45 ± 0.54^{Ca}

Note: Values in Table 4.6 are mean of 3 replicates. Mean (n=3) ± standard deviation.

A – C: Means bearing the same superscript within the same row are not significantly different at 5 % level ($p<0.05$).

a – c: Means bearing the same superscript within the same column are not significantly different at 5 % level ($p<0.05$).

Table 4.7 : Effect of Postharvest Heat and Anoxic Treatments on The B* Value on The Peel of Banana

Treatment	Week 0	Week 1	Week 2	Week 3	Week 4
Control	$29.77 \pm 0.50^{BCa*}$	31.64 ± 1.32^{Ca}	32.33 ± 1.65^{Cab}	23.50 ± 4.97^{ABa}	22.82 ± 3.06^{Aab}
Hot air 30°C	37.93 ± 12.53^{Aa}	32.06 ± 0.41^{Aa}	33.81 ± 0.43^{Ba}	26.24 ± 2.05^{Aa}	23.02 ± 2.86^{Aab}
Hot air 50°C	30.24 ± 0.66^{Ba}	32.61 ± 0.60^{Ba}	33.16 ± 0.93^{Bab}	22.90 ± 5.74^{ABa}	17.16 ± 7.44^{Aa}
Hot water 50°C	31.60 ± 2.21^{Ba}	32.90 ± 1.02^{Ba}	32.60 ± 0.47^{Bab}	22.65 ± 1.76^{Aa}	29.42 ± 0.60^{Ba}
Anoxic treatment	30.17 ± 0.22^{ABa}	32.48 ± 0.84^{Ba}	31.31 ± 0.38^{Ba}	24.50 ± 5.33^{Aa}	24.47 ± 1.91^{Aa}

Note : Values in Table 4.7 are mean of 3 replicates. Mean (n=3) ± standard deviation.

A – C : Means bearing the same superscript within the same row are not significantly different at 5 % level ($p<0.05$).

a – b : Means bearing the same superscript within the same column are not significantly different at 5 % level ($p<0.05$).

Total color change in bananas pulp is less than total color change in bananas peel. This was because chilling injury only effect on the peel. The total color changes on bananas pulp was due to the ripening process cause by ethylene as banana is climacteric fruit that can react with endogenous and exogenous ethylene to ripe. Total color changes on banana's pulp was calculated using L*, a* and b* value as showed on Table 4.8, 4.9 and 4.10.

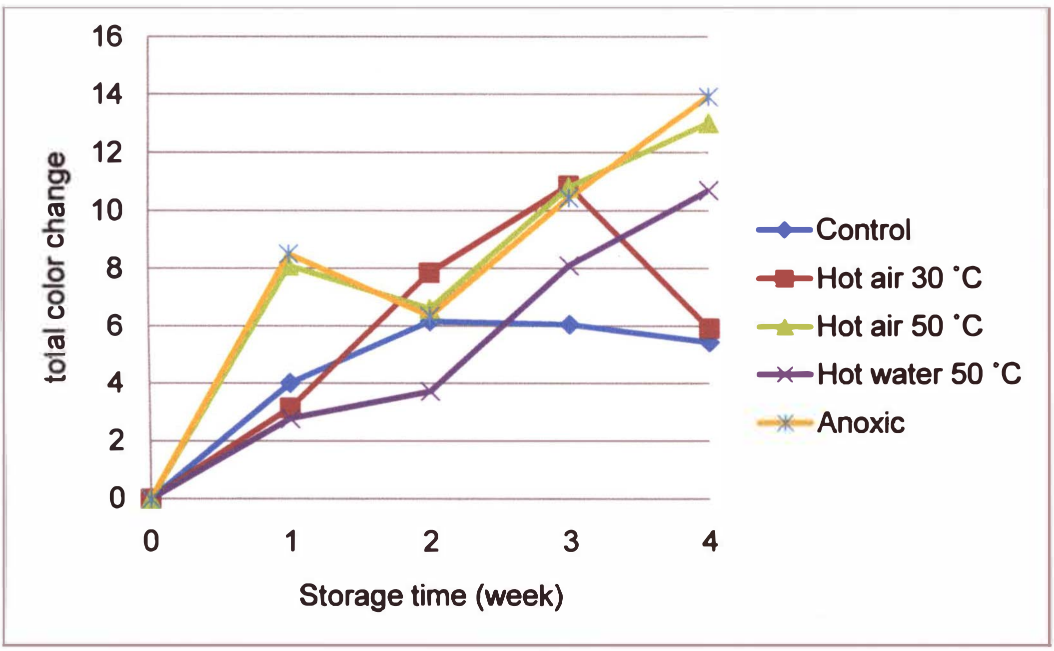

Figure 4.6: Total Color Change of Bananas Pulp Treated with Different Postharvest Treatments During Storage.

Table 4.8: Effect of Postharvest Heat and Anoxic Treatments on the L* Value on the Pulp of Banana

Treatment	Week 0	Week 1	Week 2	Week 3	Week 4
Control	$79.08 \pm 1.67^{ABCa*}$	80.09 ± 0.34^{BCa}	81.69 ± 1.85^{Ca}	73.73 ± 2.87^{Aa}	75.37 ± 3.73^{ABa}
Hot air 30°C	81.96 ± 2.60^{Ba}	80.34 ± 2.62^{Aa}	82.62 ± 2.77^{Ba}	71.54 ± 2.74^{Aa}	76.36 ± 5.19^{ABa}
Hot air 50°C	80.81 ± 6.55^{Aa}	80.11 ± 1.71^{Aa}	82.35 ± 3.28^{Aa}	76.49 ± 4.93^{Aa}	71.88 ± 6.21^{Aa}
Hot water 50°C	82.69 ± 2.76^{Ba}	82.30 ± 2.05^{Ba}	82.46 ± 2.45^{Ba}	77.74 ± 2.47^{ABa}	70.47 ± 7.78^{Aa}
Anoxic treatment	84.89 ± 1.56^{Ca}	80.85 ± 1.37^{BCa}	80.81 ± 4.20^{BCa}	77.33 ± 2.24^{ABa}	72.60 ± 2.56^{Aa}

Note: Values in Table 4.8 are mean of 3 replicates. Mean (n=3) ± standard deviation.

A – C: Means bearing the same superscript within the same row are not significantly different at 5 % level ($p < 0.05$).

a – b: Means bearing the same superscript within the same column are not significantly different at 5 % level ($p < 0.05$).

Table 4.9: Effect of Postharvest Heat and Anoxic Treatments on the A* Value on the Pulp of Banana

Treatment	Week 0	Week 1	Week 2	Week 3	Week 4
Control	1.30 ± 0.13^{Aa}	0.84 ± 0.66^{Aa}	2.40 ± 1.24^{Aa}	2.40 ± 1.24^{Aa}	2.37 ± 1.09^{Aa}
Hot air 30°C	0.91 ± 1.56^{Aa}	0.07 ± 0.24^{Aa}	1.63 ± 1.91^{Aa}	1.63 ± 1.91^{Aa}	1.31 ± 1.23^{Aa}
Hot air 50°C	0.43 ± 3.02^{Aa}	1.06 ± 1.86^{Aa}	1.52 ± 1.03^{Aa}	1.52 ± 1.03^{Aa}	2.97 ± 1.46^{Aa}
Hot water 50°C	0.31 ± 1.33^{Aa}	-0.53 ± 1.9^{Aa}	1.35 ± 1.40^{Aa}	1.35 ± 1.40^{Aa}	2.59 ± 2.04^{Aa}
Anoxic treatment	-1.46 ± 0.12^{Aa}	1.01 ± 1.57^{ABa}	2.70 ± 2.37^{Ba}	2.70 ± 2.37^{Ba}	2.29 ± 0.70^{Ba}

Note: Values in Table 4.9 are mean of 3 replicates. Mean (n=3) ± standard deviation.

A – B: Means bearing the same superscript within the same row are not significantly different at 5 % level ($p < 0.05$).

a – b: Means bearing the same superscript within the same column are not significantly different at 5 % level ($p < 0.05$).

Table 4.10: Effect of Postharvest Heat and Anoxic Treatments on The B* Value on The Pulp of Banana

Treatment	Week 0	Week 1	Week 2	Week 3	Week 4
Control	33.30 ± 3.4^{Aa}	31.84 ± 1.65^{Aa}	31.50 ± 2.80^{Aa}	34.14 ± 2.01^{Aa}	31.23 ± 1.89^{Aa}
Hot air 30°C	32.23 ± 2.29^{ABa}	32.33 ± 2.36^{ABa}	30.41 ± 0.59^{ABa}	34.39 ± 1.50^{Ba}	29.49 ± 0.74^{Aa}
Hot air 50°C	30.5 ± 2.02^{Aa}	33.18 ± 1.84^{Aa}	32.82 ± 2.73^{Aa}	32.78 ± 0.43^{Aa}	32.49 ± 3.15^{Aa}
Hot water 50°C	31.17 ± 0.77^{Aa}	30.39 ± 2.96^{Aa}	33.02 ± 1.73^{Aa}	35.39 ± 2.88^{Aa}	30.17 ± 2.80^{Aa}
Anoxic treatment	29.62 ± 0.53^{Aa}	38.81 ± 4.22^{Aa}	30.51 ± 1.27^{Aa}	34.70 ± 2.38^{Aa}	33.50 ± 1.85^{Aa}

Note: Values in Table 4.10 are mean of 3 replicates. Mean (n=3) ± standard deviation.

A – B: Means bearing the same superscript within the same row are not significantly different at 5 % level ($p < 0.05$).

a – b: Means bearing the same superscript within the same column are not significantly different at 5 % level ($p < 0.05$).

There is no significantly different among all the treatments in terms of L* value starting from week 0 to week 4. This showed there is no changes of L* value over the storage time. There is also no significantly different at the a* value of all the treatment starting from week 0 until week 4. Same goes to value of b* on banana's pulp. There is no significant different of all the treatment beginning from the first week until the last week of storage. This indicating that all the treatments were not affecting the value of L*, a* and b* of the banana's pulp. This is relevant to the fact that chilling injury will not affecting the physical appearance of the pulp.

4.5 TBA Reactive Substances Value

Thiobarbituric acids reactive substances (TBARS) were determined and expressed as malondialdehyde (MDA) equivalents, according to the method of Shahidi and Hong (1991) with slight modifications. The mixture of banana peel extract with TBA and TCA acids will give red clear color if the chilling injury exists. The TBARS values were presented in the Figure 4.7 below.

From the above figure, we can see that all the treatment increased in their malondialdehyde contents due to chilling injury process during and after storage. At the first week the control and hot air 50°C treatment show some big different on the graph scale. However there is significant difference ($p<0.05$) between control and anoxic treatments. This happened because the banana may have some physical injury that can affect the result. But the trends not show so much different at the last 3 week as chilling injury increase by week. Anoxic treatment show the best result as it have the lowest TBA value on the last week. Hot air 30°C is significantly different ($p<0.05$) and showed the highest TBA value contents as it have the highest chilling injury on the banana's peel. The malondialdehyde is a lipid peroxidation products that cause due to chilling injury. By measuring the malondiadehyde contents, we can know how much chilling injury had occurs on the banana. There is no significanly different among all treatments on week 0, week 2 and week 3.

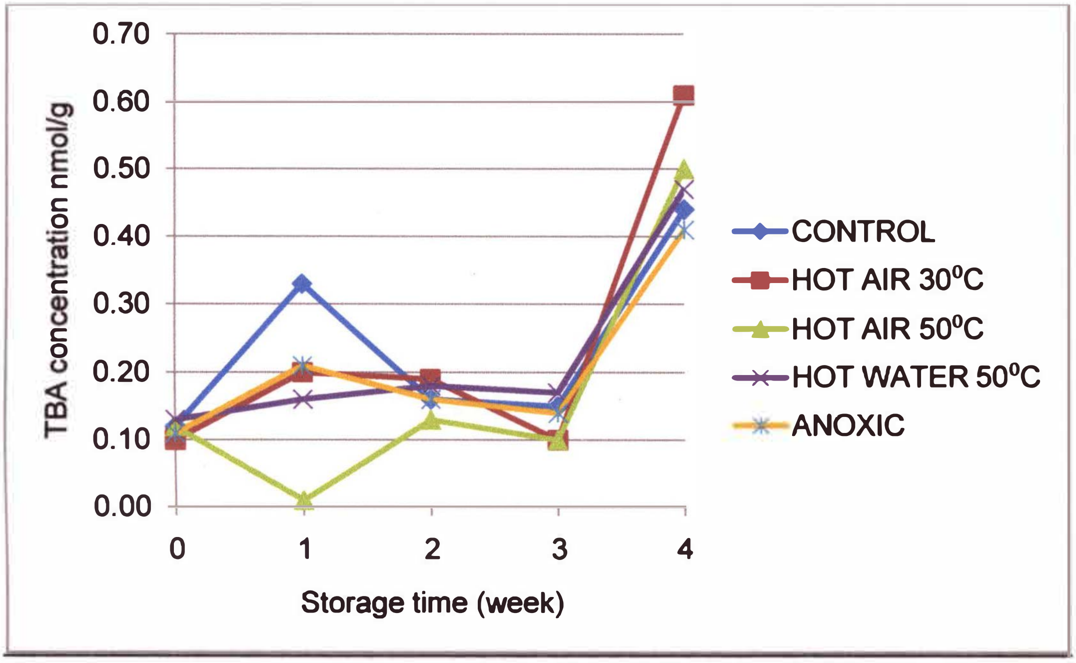

Figure 4.7: The TBA Value of Bananas Treated with Different Postharvest Treatments During Storage.

But the statistical analysis showed some changes on week 1 and week 4. On week 1, control is significantly different ($p<0.05$) than other treatments as showed in Table 13. In the meantime, hot air 30°C is significantly difference to the other treatment on the last week of storage. The highest mean of TBA value was in the hot air 30 °C treatment indicated that there are more chilling injury occurred when the bananas were treated using this method.

Table 4.11: Effect of Postharvest Heat and Anoxic Treatments on the TBA Value on the Peel of Banana

Treatment	Week 0	Week 1	Week 2	Week 3	Week 4
Control	0.01 ± 0.01^{Aa}	0.05 ± 0.02^{Bcb}	0.03 ± 0.01^{ABa}	0.02 ± 0.00^{Aa}	0.01 ± 0.01^{Ca}
Hot Air 30	0.02 ± 0.00^{Aa}	0.03 ± 0.01^{Aab}	0.05 ± 0.02^{Aa}	0.02 ± 0.01^{Aa}	0.10 ± 0.00^{Bb}
Hot Air 50	0.02 ± 0.00^{Aa}	0.02 ± 0.00^{Aa}	0.02 ± 0.00^{Aa}	0.02 ± 0.00^{Aa}	0.08 ± 0.02^{Bab}
Hot water	0.02 ± 0.01^{Aa}	0.02 ± 0.00^{Aab}	0.03 ± 0.01^{Aa}	0.03 ± 0.01^{Aa}	0.07 ± 0.00^{Ba}
Anoxic	0.02 ± 0.00^{Aa}	0.03 ± 0.00^{Cab}	0.03 ± 0.00^{Ba}	0.02 ± 0.00^{ABa}	0.06 ± 0.00^{Da}

Note : Values in Table 4.11 are mean of 3 replicates. Mean (n=3) ± standard deviation.

A – D : Means bearing the same superscript within the same row are not significantly different at 5 % level ($p<0.05$).

a – c : Means bearing the same superscript within the same column are not significantly different at 5 % level ($p<0.05$).

CHAPTER 5

CONCLUSION

5.1 Conclusion

The demand of bananas is increasing but the short life due to perishable nature creates difficulty in the export of this fruits in the international market. The objective of the present study was to maintain of bananas during storage at its optimum temperature and reduce the manifestation of chilling injury which can lower the shelf life and quality of bananas. The result from the study shows that anoxic treatment was the best treatment which can be applied to banana to prolong the shelf life during storage. Anoxic treatment can reduce the chilling injury symptom on the banana's peel as supported in the study. Hot air treatment 30°C is not the best treatment to be applied as the treatment will cause damage to the banana especially on the peel. This will reduce the consumer acceptability as the physical appearance of the product is not attractive and not guaranteed the condition of the pulp.

5.2 Recommendations

For the future research, it is recommend that the addition of parameters to include the determination of toxic compound that present in the banana that have infected by chilling injury. This is because storing produce at low temperature will cause the productions of toxic compound such as ethanol and acetaldehyde which lead to cellular disruption. These compounds arise from an inability of membrane as to cellular disruption. These compounds arise from an inability of membrane as associated enzymes in the mitochondria to metabolize product of glycolysis. Produce that are able to survive for long period the break temperature are assume to have metabolic system that can overcome the metabolic block and thus prevent the accumulation of toxic compound. This is very important to determine the safety of the produce which can affect the health of consumer.

Since anoxic treatment using N_2 gave the best effect in this study, further study involving other different noble gases such as Argon, could also be studied. The different in exposure time to anoxic treatment might also have certain effects on the manifestation of chilling injury which worth studying.

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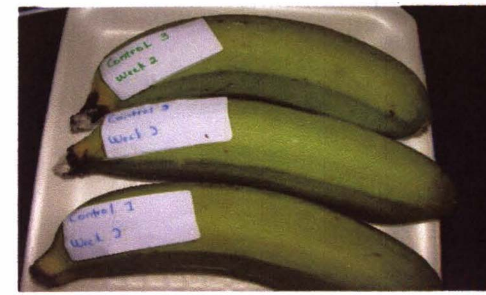
Appendix A

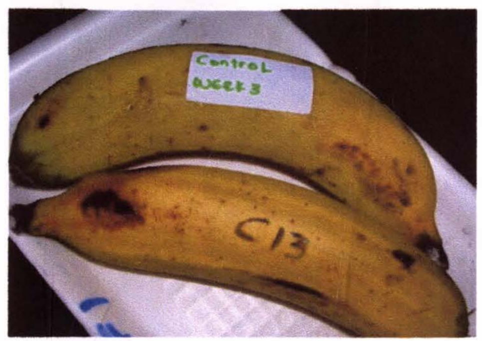
CONTROL

Week 0

1ST Week



2ND Week



3RD Week

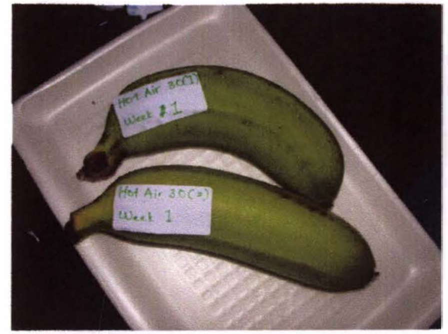
4TH Week

The Conditions of The Control Bananas at Different Week.

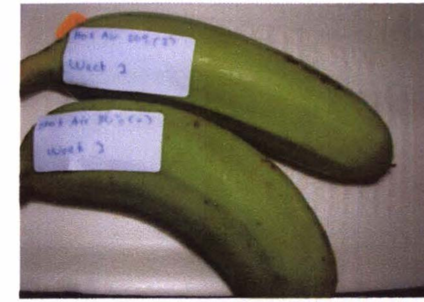
Appendix B

HOT AIR (30˚C)

DAY 0



1ST WEEK



2ND WEEK

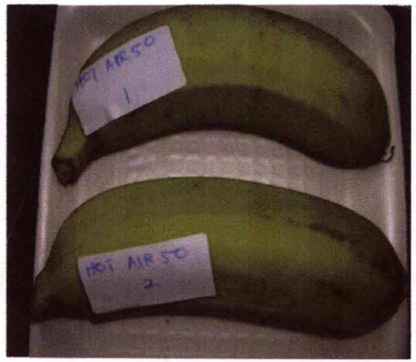
3RD WEEK

4TH WEEK

The Conditions of The Bananas Treated With Hot Air (30°C) at Different Week.

Appendix C

HOT AIR (50˚C)



Week 0

1st week

2nd week

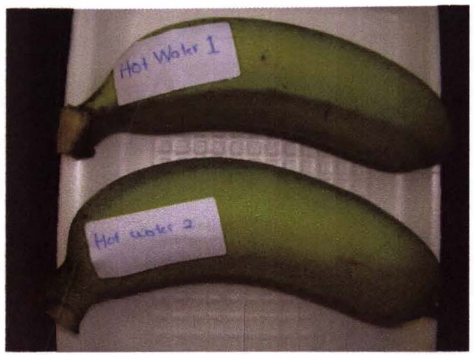
3rd week

4th week

The Conditions of The Bananas Treated With Hot Air (50°C) at Different Week

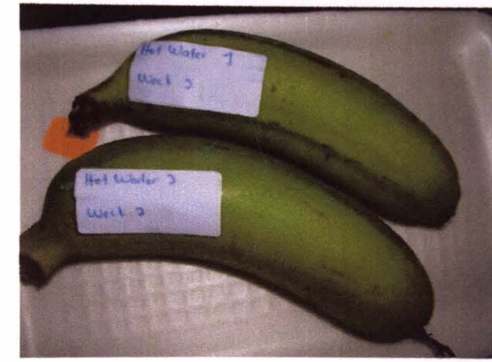
Appendix D

Hot water (50° C)



Week 0

1st week



2nd week

3rd week

4th week

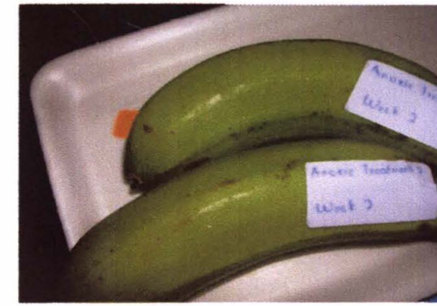
The Conditions of The Bananas Treated With Hot Water (50°C) at Different Week

Appendix E

Anoxic Treatment

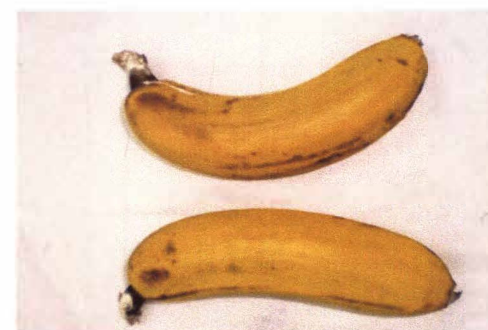
Week 0

1st week



2nd week

3rd week



4th week

The Conditions of The Bananas Treated With Anoxic Treatment at Different Week

CURRICULUM VITAE (CV)

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ex	: Male
arital Status	: Single
ealth	: Good
ace	: Malay
eligion	: Islam
itizen	: Malaysian
eight / Weight	: 175 cm / 54 kg
obbies / Interest	: Playing football
anguage (Written)	: English (GOOD)

: Malay (GOOD)

nguage / (Spoken) : English (GOOD)

: Malay (GOOD)

ORKING EXPERIENCES

- Industrial practical at MADA for 4 months.
- Worked at Batas Murni Sdn.Bhd, a company that specializes in meat storage and packaging for 3 months.

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'07-2008 (latest) : 1st semester (2.04),2nd semester (2.89)

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UPSR: 3As and 2Bs

OMMUNICATION AND INTERPERSONAL SKILLS

- Have the ability and experiences to conduct farm works
- Can conduct Microsoft Word, Microsoft Power Point, Microsoft Excel
- Have good knowledge in post harvest
- Have both driving licenses (car and motorcycle)
- Have experiences in fisheries management
- Have good knowledge in crop protections and pomology
- Good both in English and malay

: Malay (GOOD)

nguage / (Spoken) : English (GOOD)

: Malay (GOOD)

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PMR: 3As and 5Bs

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UPSR: 3As and 2Bs

OMMUNICATION AND INTERPERSONAL SKILLS

- Have the ability and experiences to conduct farm works
- Can conduct Microsoft Word, Microsoft Power Point, Microsoft Excel
- Have good knowledge in post harvest
- Have both driving licenses (car and motorcycle)
- Have experiences in fisheries management
- Have good knowledge in crop protections and pomology
- Good both in English and malay

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)99 – 2003	: School representative in badminton tournament
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	: Committee members of Editorial Board for school's magazines
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EFFECTS OF POSTHARVEST HEAT AND ANOXOC TREATMENTS ON THE MANIFESTATION OF CHILLING INJURY IN 'BERANGAN' BANANA - MEGAT HAZEQ BIN MEGAT HASHIMI