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Effects of selected anti-browning treatments on the storage
quality of fresh-cut banana / Nurul Syazila Abd Rani.

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**EFFECTS OF SELECTED ANTI-BROWNING TREATMENTS ON THE STORAGE
QUALITY OF FRESH – CUT BANANA**

By

Nurul Syazila Bt Abd Rani

**Research Report submitted in partial fulfillment of
the requirements for the degree of
Bachelor of Science in Agrotechnology (Post Harvest Technology)**

**DEPARTMENT OF AGROTECHNOLOGY
FACULTY OF AGROTECHNOLOGY AND FOOD SCIENCE
UNIVERSITI MALAYSIA TERENGGANU
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ENDORSEMENT

The project report entitled **Effects of Selected Anti-Browning Treatments on the Storage Quality of Fresh-Cut Banana** by **Nurul Syazila bt Abd Rani** Matric Number **UK15115** 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

Anti-browning agents are the edible chemical that can be used to reduce the damage and spoilage that occurs on the fresh produces due to enzymatic browning when the produces are being cut especially for minimally process (MP) industry. Enzymatic browning is a chemical reaction which occurs in fruits and vegetables by the enzyme polyphenoloxidase which reacts in the presence of oxygen, which resulted in brown pigments, which is also known as *o-quinone*. Enzymatic browning is detrimental to quality, particularly in post-harvest storage of fresh fruits and fruits products. Enzymatic browning may be responsible for up to 50% of all losses during fruit and vegetables production. The effectiveness of three different anti-browning agents were investigated individually or in combination on the MP sliced banana. The anti-browning agents used in this study were glutathione (0.5 M), N-acetylcysteine (0.05 M), citric acid (0.5 M), combination of glutathione (0.5 M) and citric acid (0.5 M), combination of N-acetylcysteine (0.05 M) and citric acid (0.5 M) where MP sliced banana without any treatment served as Control. The storage quality of the tested MP sliced bananas were assayed in terms of their total color change and physico-chemical characteristic (texture, titratable acidity, pH, percentage of weight loss, total soluble solid and browning index) over the chilled storage at $5\pm 1^{\circ}\text{C}$; relative humidity (RH) 95% for 15 days. All the treatments showed increasing patterns in total color change, pH, percentage of weight loss, total soluble solid and browning index over the storage. However, texture and titratable acidity were decreasing. The rate of increasing and/or decreasing of each parameters were different among the treatments. The combination of N-acetylcysteine (0.05 M) and citric acid (0.5 M) was the most effective inhibitory of browning activities in sliced bananas.

ABSTRAK

Agen penyahperang adalah bahan kimia yang boleh dimakan yang digunakan untuk mengurangkan kerosakan dan kemusnahan yang berlaku kepada produk segar yang disebabkan oleh keperangan berenzim apabila produk segar tersebut dipotong terutama sekali untuk industri pemprosesan minimal. Keperangan berenzim adalah satu tindakbalas kimia yang berlaku kepada buah-buahan dan sayur-sayuran oleh enzim polifenoloksida yang berlaku dengan kehadiran oksigen dan mengakibatkan terjadinya pigmen berwarna perang, juga dikenali sebagai *o-kuinon*. Keperangan berenzim akan mendatangkan keburukan dari segi kualiti, terutamanya kepada penyimpanan lepas tuai buah-buahan segar dan produk-produk berasaskan buah-buahan. Keperangan berenzim boleh menyumbang kepada hampir 50% kehilangan hasil pengeluaran buah-buahan dan sayur-sayuran. Keberkesanan tiga agen penyahperang telah dikaji secara individu atau secara kombinasi terhadap proses minimal hirisan pisang. Agen penyahperang yang digunakan dalam kajian ini adalah glutation (0.5 M), N-asetilsisteina (0.05 M), asid sitrik (0.5 M), kombinasi glutation (0.5 M) dan asid sitrik (0.5 M), kombinasi N-asetilsisteina (0.05M) dan asid sitrik (0.5 M), manakala proses minimal hirisan pisang tanpa agen penyahperang bertindak sebagai kawalan. Kualiti penyimpanan terhadap proses minimal hirisan pisang yang telah disei dari segi perubahan warna keseluruhan dan ciri-ciri fiziko-kimia (tekstur, asid tertitrat, pH, peratus kehilangan berat, jumlah pepejal larut, dan index keperangan) sepanjang penyimpanan sejuk-dingin pada suhu $5\pm 1^{\circ}\text{C}$; kelembapan relatif (RH) 95% selama 15 hari. Semua rawatan menunjukkan peningkatan dalam perubahan warna keseluruhan, pH, peratus kehilangan berat, jumlah pepejal larut, dan index keperangan sepanjang tempoh penyimpanan. Walau bagaimanapun, tekstur dan asid tertitrat menunjukkan penurunan. Kadar peningkatan dan/atau penurunan setiap parameter adalah berbeza antara rawatan-rawatan yang terlibat. Kombinasi N-asetilsisteina (0.05 M) dan asid sitrik (0.5 M) merupakan rawatan penyahperangan yang paling berkesan bagi hirisan pisang.

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LIST OF ABBREVIATIONS

°C	Degree Celsius
kg	Kilogram
%	Percent
cm	Centimeter
µg	Microgram
g	Gram
MP	Minimally process
ppm	Part per million
L	Liter
mg	Milligram
w/v	Weight/volume
RM	Ringgit Malaysia
HACCP	Hazard Analysis Critical Control Point
GMP	Good Manufacturing Practices
GHP	Good Hygiene Practices
GDP	Good Distribution Practices
TSS	Total soluble solid
USDA	United States Department of Agriculture
PPO	Polyphenoloxidase
GRAS	Generally Recognized As Safe
$C_{10}H_{17}N_3O_6S$	L-Glutathione reduced
$C_5H_9NO_3S$	N-acetyl-L-cysteine
$C_6H_8O_7$	Anhydrous citric acid
NaOH	Sodium Hydroxide
$CaCl_2$	Calcium chloride

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Bananas or *Musa paradisiaca* have been cultivated for over 2000 years. In the Qoran there is a plant referred to as "the tree of paradise" which is believed to be a banana plant. Alexander the Great told of seeing the sages of India eating a fruit, which closely resembled the banana. All indications lead us to believe bananas originated in Asia. Some of the most primitive species of banana are still found growing wild in this region (Vandamme, 2009).

Bananas were propagated around the world by early explorers. When the Spanish explored the Western hemisphere in the 16th century, they brought over banana plants and introduced them to South and Central America and the Caribbean. Today there are over 500 documented names for different banana varieties, yet they are not all classified as individual species. Due to the banana, plants' tendency to "sport" or mutate very easily, taxonomists gave up long ago trying to classify them all. Only the plants, which are capable of reproducing by seed (diploid), have been classified into species (Hassan and Pantastico, 1990).

The seedless types (triploid) have been left to be referred to by their local names, called varieties. The seedless bananas, which are the varieties cultivated for food, reproduce by production of "suckers" or ratoons. These are shoots off the main root or "corm" of the plant (Hassan and Pantastico, 1990). Banana is a well-known tropical fruit that is traded all over the world whether in the raw or processed form.

According to Mohd Nor (2009), the area under the cultivation of banana in Peninsular Malaysia has been estimated approximately at 17, 710 hectares (43,763) in 1976, which is about 33 years ago. The area has been developing larger due to modern and new technology parallel to the increasing demands of the cultivation worldwide.

Banana actually originated from the tropical region of East West Asia, which covered from India, Thailand, Malaysia, and Indonesia to Philippine (Hassan and Pantastico, 1990). In Malaysia, the planting area of banana covered from the south to the north Malaysia, this is from Johor to Perlis. This is because, the type of soil in Malaysia is suitable for this plant and it can grow very well at the place where it gets sufficient sunlight with optimum temperature of about 25 – 32°C (FAMA, 2009).

1.2 Problem statement

The banana is one of the tropical fruits that facing a high demands throughout the whole years. In the process of making the fresh cut of banana, the main problem that will be encountered by the supplier is the browning process which affecting the fruit as it has been peeled off and sliced into required pieces (Apintanapong *et al.*, 2007). Browning is a process that takes place when the polyphenol oxidase (PPO) reacts with oxygen in the air. Browning will lead to the degradation of fresh cut produce and thus affect its quality (Mérimeé *et al.*, 2003). As the result, banana will turn to darker color and unpleasant odor and the other visual characteristics that can be observed such as, the surface of the banana will become sticky and shrink due to the water loss.

Most serious problem in handling the processed banana is the browning process, which occurs greatly on the peeled banana. There are several ways to

control the enzymatic problems, including the use of several chemicals, which act as the anti-browning agents, such as the carboxylic acid, ascorbic acid, sulfur containing amino acid and others, which include the calcium chloride and sodium chloride (Apintanapong *et al.*, 2007).

As the people who are working in the field of post harvest technology, maintaining the quality of certain produces right from harvesting process until the produces reach the hand of consumers in acceptable condition based on the criteria determined by the food laws and major concern. If the process of keeping or maintaining the quality of the banana or other agriculture produces is not being attempted very carefully, the produces will not reach the specification that has been agreed and this will cause major loss for the farmers who work really hard for that.

1.3 Significance of study

The increase in consumers' awareness of health benefits from consuming the fresh-cut fruits and vegetables nowadays, drive the food industries to try harder to reach the demands of the consumers from the aspects of products quality and safety in order to compete among each other to be the best food suppliers in fresh-cut industry (Son *et al.*, 2000). The significance of this study is to discover a new post harvest treatment for fresh-cut banana, especially banana in sliced forms, which normally consumed as battered fried banana, which is one of well-known side dishes in Malaysia.

Minimally processing can also guarantee the safety and hygiene of the products; therefore, the consumers no need to have doubt in their heart when it comes to consuming minimally processed products. Minimally processed products are the products that are being processed under the applications and implementation

of Food Safety Act in 1983 under act 281. Food safety is a worldwide concern and official control of food safety in many countries is legislated via Food Safety Act and Regulations in 1983 and 1985 (Laws of Malaysia, 2006). Legislation on the safety of foodstuffs requires HACCP (Hazard Analysis Critical Control Point) which is based on the food safety management systems to be in place by all food establishments.

The food safety requirements are comprises of Good Manufacturing Practices (GMP), Good Hygiene Practices (GHP), Good Distribution Practices (GDP) and many more (Wong, 2004). Therefore, the quality and the safety of the products are under control starts from the processing line to distribution line until it reaches the consumers' hands (Figure 1.1).

Nowadays people live in a very hectic life and spend less time in the kitchen to prepare for the food. They tend to eat at the restaurant or stall without paying a very serious attention to the hygiene and cleanliness of the food and the surrounding of the places. Therefore, in the development of post - harvest technology, the rise of foods, whether fruits or vegetables in the form of minimally process has becoming more popular. The minimally process of banana especially in the sliced form will make the life of consumers easier when it comes to preparing the quality, delicious and nutritious food for their family (Figure 1.2).



Figure 1.1: Minimally processed banana in a convenient pack



Figure 1.2: Battered fried banana as one of popular side dishes in Malaysia.

The minimally processed sliced banana will also cut down the cost of transportation because the supplier does not have to pay for the inedible banana skin and unwanted bunch. Besides, the fresh cut banana that has been treated with the selected anti-browning agent can be kept for longer period of time and easier to be handled without comprising larger storing area (Altunkaya and Gökmen, 2007).

1.4 Objectives

The main objective of this study is to investigate and observe the effects of different anti-browning agents on the storage quality of fresh-cut banana.

1.4.1 Specific objectives

- 1) To determine the physico-chemical changes of fresh cut banana treated with a few selected anti-browning agents during chilled storage.

CHAPTER 2

LITERATURE REVIEW

2.1 Banana

Banana is a special type of berry fruit that the peel can be easily taken off and the fruit does not develop from the seed box wall but from the receptacle in which the seed box is embedded. The pericarp of the fruit is composed of an external layer, the epidermis is consisting a single layer of cells with stomata and a well-defined cuticle on the outer surface (Israeli and Lahav, 1986).

‘Pisang Awak’ or *Musa x paradisiaca* (ABB group) (*cv. awak*), is the cultivar that mostly grown in Thailand and Malaysia. The common name of the cultivar is ‘pisang awak’, which is well known in Western Malaysia, and the cultivar is known as ‘pisang kelat siang’ in Eastern Malaysia. The normal bunch weight of this variety is about 18 - 22 kg, with 8 – 12 hands and 10 – 16 fingers per hand. The fruit is small to medium in size and turn to pale yellow when it ripens. The finger length is about 10.0 -15.0 cm with diameter of approximately 3.0 - 4.0 cm (Hassan and Pantastico, 1990).

The Banana as we all know is a long thick-skinned edible fruit that will turn to yellow from green in color when ripens (Figure 2.1). The fruits are arranged in the hands or combs on the single inflorescence, which is known as the fruit bunch (Figure 2.2). The peduncle of the inflorescence will bend down due to the increasing weight of the developing banana fruits as the fruits growing bigger and become mature (Figure 2.3).



Figure 2.1: 'Pisang awak' at the maturity stage 4, which normally used for battered fried banana.



Figure 2.2: A bunch of 'pisang awak' on the tree.

Banana can be easily obtained and sold at affordable prices. It contains a lot of mineral, vitamin and water. The percentage of vitamin C in a finger of banana is higher than the percentage of vitamin C in an apple (Mohd Nor, 2009).



Figure 2.3: The structure of *Musa x paradisiaca* (ABB Group) cv.pisang awak plant.

For the best quality of banana, it needs the best preharvest procedures, which are start as early as the plant is being planted at the farm. The preharvest procedures include the climatic factors and cultural factors. The climatic factors include the light and relative humidity factors that will influence the cosmetic outcome and the storage life of the fruits when they mature and ripe after harvest (Hassan and Pantastico, 1990).

Fruits that developed under the insufficient light undergo retarded development of carotenoids pigments and the fruits possess a very dull yellow peel color and might not be attractive to the eyes of the consumers. The high relative humidity to the plant and to the fruits during the development of the fruits while the fruits still attach to the plant will cause the short storage life of the fingers and high incidence of fingers drop and cause the crown rotting of the fruits. The preharvest procedures also comprise the cultural factors, which include the minerals and nutrients, irrigation, thinning, and fertilizing the plant. The best preharvest procedures will give the best post harvest outcome (Hassan and Pantastico, 1990).

In the post harvest field, the most important thing is to keep the produce in the best condition, extending the shelf life or the storage life of the produce at the optimum quality that can be accepted and consumed by the buyers or the consumers. Storing the produce is a way to maintain the quality after harvest. The systematic storage technique will maximize the shelf life of the fruit and this is very important in exporting the produce to distance markets. The produce need to maintain the quality, cosmetic factors, taste and the aroma until it reaches the selected destination and being consume by the consumers.

2.2 Minimally processing

Minimally processing is a process done to the agricultural produces mostly fruits and vegetables, which involve minimal process of preparation that enable the consumers to use the products immediately after purchase (Bico *et al.*, 2008). Normally the processes involved are different according to the type of fruits or vegetables required by the market. These processes including peeling, washing, slicing, precooling, and packaging processes (Son *et al.*, 2000). In fact, the processes are a little bit different depends on the produce itself.

Fruits or vegetables that are processed by this method tend to damaged quicker if compared to the intact produces. The proper storage and handling methods during minimally processing can minimize the damage to the optimum limit. According to Mohd Nor (2009), mangosteen and jackfruit that are being minimally processed can be stored for 3 weeks at 2°C, 7 days at 10°C and 2 days at 25°C. Pineapple, orange, melon, and mix fruits can be stored for 2 weeks at 2°C, 7 days at 10°C and 2 days at 25°C.

The advantages of minimally process are; it can provide the essential vitamins and nutrients to the consumers at lower cost and less preparation time. It also can save the cost of transportation and ease the handling and storage process for the consumers. The minimally process products can be stored in the typical home refrigerator temperature (Mohd Nor, 2009).

2.2.1 Degradation of MP fruits during storage

MP products will undergo several major degradation, which will limit the storage time and the quality of the products itself. So in order to overcome the problems, research should be done to minimize the degradation process so that consumers can consume the products for longer period of time.

2.2.1.1 Changes in color

The most obvious change in many minimally processed fruits or vegetables is the color. Color plays a very important factor in influencing and convincing consumers to purchase the products. In tomatoes, the level of chlorophyll is progressively broken down into phytol. It was observed that in cherry tomatoes the total chlorophyll level was reduced from 5490 μg per 100 g fresh weight in green fruit to 119 μg per 100 g fresh weight in dark – red fruit (Laval-Martin *et al.*, 1975). Concurrent with this degradation process, lycopene, carotenes and xanthopylls are synthesized and give the fruit the characteristic color, usually red or dark related color. Total carotenoids in cherry tomatoes increased from 3297 μg per 100 g fresh weight in green fruit to 11 694 μg 100 g fresh weight in dark-red fruits. This color development occurs in both the pulp and the flesh of the tomatoes (Laval-Martin *et al.*, 1975). Great color changes to the MP fruits or vegetables will cause consumers

unacceptance and this will reduce the MP products demands due to low aesthetic value of the products.

2.2.1.2 Changes in texture

Texture and food structure are inextricably linked; the micro- and macro structural composition of foods will determine the sensory perception, and any change in structure carries the risk of changing perceived texture and violating consumer expectations. Industry therefore needs to take great care to ensure that products with key textural characteristics. This can present an enormous challenge for foods relying on primary components such as meat and vegetables that are naturally subject to high variability, and for any processed food manufactured on high-volume production lines. Product modifications, for example to produce low-fat variants, can introduce structural changes that can generate substantial textural modifications. Industry therefore needs methods to measure textural characteristics. However, designing suitable measurement systems requires an understanding of the mechanisms by which texture is perceived (Kilcast, 2004).

Fruits and vegetables normally soften progressively during ripening, storage and processing due to breakdown of internal and external tissues. Instrumental measurement of fruit texture needs careful application and interpretation to ensure they are relevant to organoleptic perception of the products texture. Although exact biochemical mechanisms have not yet been established and studied for further explanation, it is believed that texture changes and softening of the MP fruits and vegetables is greatly due to the breakdown of starch and other non-pectic polysaccharides in the pulp and in the flesh itself, whereby reducing cellular rigidity and firmness (Lizada *et al.*, 1990).

During ripening and storage of the products after processing activities accomplished, there are three major changes in the pectic polymers in the cell walls (Tucker and Grierson, 1987). Neutral sugars, mainly galactose in most fruit but also some loss of arabinose, which are major components in cell wall neutral pectin, are lost. There are also losses of acidic pectin.

The solubility of these polyuronids increases and in several cases shown to be progressively depolymerized (Tucker and Grierson, 1987). Sirisomboon et al. (2000) also found that the solubilization of non-soluble pectin to water-soluble pectin appeared to influence the texture of Japanese pears.

2.2.1.3 Changes in nutritional composition

Not much research studied about the nutritive value, i.e., vitamin, sugar, amino acid, fat and fiber content of minimally processed produce. Washing does not decrease the vitamin content (C vitamin and carotenes) of grated carrot, shredded Chinese cabbage or peeled potatoes significantly. Fresh tomatoes and other processed tomato products make a significant contribution to human nutrition owing to the concentration and availability of several nutrients in these products and to their widespread consumption. Composition tables show that ripe tomato (*Lycopersicon esculentum*, Mill.) contains 93–95% water and low levels of solid matter (Leoni, 2002).

2.2.1.4 Changes in total soluble solid (TSS)

Brix is referred to as the "sugar" or sucrose content of a plant or the produce from it, but this is a very simplistic and incomplete view of Brix. Although a high Brix value certainly indicates high sugar content, in actuality, Brix refers to the total soluble solids (TSS) in the juice of the produce or sap of the plant. Total soluble solids refers not only to sucrose (sugar) but also to fructose, vitamins, minerals, amino acids, proteins, hormones, and other solids found in the plant, fruit or vegetable. The higher the TSS or Brix value, the healthier and more nutrient/mineral rich the plant or produce is (Wills *et al.*, 1981).

Over storage time of MP products, the value of the sugar content will rise due to degradation of organic acid to sugar. Thus, causing the fruits or vegetables that have been processed tends to be sweeter in taste and the sourness of the produce will decrease.

2.2.1.5 Changes in pH

PH is a measure of the acidity or alkalinity of a solution. Minimally products do have change in pH value. This is because of organic acid, mostly citric acid and malic acid that are naturally contained in the fruits or vegetables have degraded to sugar, which give sweeter taste to the products. Thus, reducing the pH value of the products. Decreasing pH also will result to the less sour taste of the fruits.

2.2.1.6 Changes in microbial counts

Minimally processed of fruits and vegetables generally will support rapid growth of microorganisms and the value of microbes counts are mostly 10^7 to 10^8 CFU/g (Nguyen *et al.*, 1994). For the growth of microflora in minimally processed of fruits and vegetables, pH is very important factor. This is because less-acid tolerant

organisms generally contaminate vegetables, while fruits are generally can be contaminated with more acid-tolerant bacteria and fungi. For a particular product, mesophilic bacteria that are count during the beginning of storage can be a useful indicator of storage stability. Mesophilic bacteria are highly variable and range from 10^3 to 10^9 CFU/g. Products quality is often can be acceptable despite such high counts (Gunes *et al.*, 1997).

Although the incidence of food-borne illnesses linked to fresh produce is low, there is an increased awareness that fruits and vegetables can be contaminated with microbiological pathogens. Two microbiological pathogens that can cause food-borne illnesses were present in the fresh produce: *Salmonella* and *Shigella*. With the shift in diet toward the consumption of more fresh fruits and vegetables and greater distribution distances from new geographic sources, there are more reported illnesses involving fresh produces (Tauxe *et al.*, 1997).

The safety of the MP products is very important to make sure that the products are safe to be consumed. The MP products should be tested and well monitored regularly. This can be achieved by implementing the Good Manufacture Practices (GMP), Good Distribution Practices (GDP) and Hazard Analysis Critical Control Point (HACCP).

2.3 Treatments for minimally processed fruits

Treatment done to the minimally processed fruits is a very important step in order to protect the fruits from damaged due to microbial and pyhsico-chemical changes such as the activity of the PPO, the color and the texture of the fruit which will reduce the cosmetic value of the products. If that so, the products will not be

bought by the consumers anymore. The treatments can be in the form of physical or chemical treatments.

2.3.1 Physical treatments

2.3.1.1 Reducing oxygen availability

It is important to consider that as a requirement of living tissues, fresh-cut products cannot be exposed to the environments with complete removal of oxygen. Nevertheless, enzymatic browning can be delayed (in the presence of active enzyme and phenolic substrate) if oxygen is not available for the reaction to take place.

Modified atmosphere packaging. Among other benefits the use of modified or controlled atmosphere retards senescence and consequently extends storage life of products. Modified or controlled atmosphere should be seen as a supplement to adequate management of temperature and controlled humidity (Kader, 1992).

Modified atmosphere packaging aims at the creation of an ideal gas composition in the package, which can be achieved through; (1) Commodity generated modified atmosphere in the package, and (2) through the establishment of an active modified atmosphere in the package. However, it is important to avoid damaging low levels of oxygen or high levels of carbon dioxide, which lead to anaerobic respiration, resulting in the development of off-flavors and odor and increasing susceptibility to decay. Appropriate gas composition of modified atmosphere need to be experimentally determined for each particular product (Wills *et al.*, 1998). Using a moderate vacuum packaging with polyethylene (80 μm) for the storage of shredded Iceberg lettuce at 5°C, browning was inhibited over 10 days periods (Heimdal *et al.*, 1995). Browning of commercially prepared cut lettuce was

retarded in packaged product, where the atmosphere was altered by the respiring products. Visual quality of the cut lettuce packaged in sealed bags receive an original score of 9 (excellent), after storage for 2 weeks at 2.8°C at the score dropped to 7 (good), while samples stored in unsealed package received a score of 3 (poor). Modified atmosphere packaging was also efficient in controlling microbial buildup during storage (King *et al.*, 1991)

2.3.1.2 Reducing temperature

Temperature control is commonly used to prevent or minimize the microbial spoilage of foods. Although refrigeration of fruits and vegetables does not completely inhibit microorganisms, it reduces the growth rates of some spoilage organisms and food borne pathogens. The effect of temperature on the survival and activity of pathogens on fresh-cut produce is not widely reported in the literature, and most reports focus on *L.monocytogenes*. Storage of processed fruits and vegetables at refrigeration temperatures may deter the growth of mesophilic pathogens but will not necessarily prevent survival and growth of *L.monocytogenes* or *Aeromonas hydrophila* (Elizabeth and Diane, 2009).

2.3.1.3 Gamma radiation

Application of gamma radiation to fruits and vegetables has been used for insects and disease disinfection, as well as to retard ripening and sprouting. Irradiation applied to fresh-cut carrots stored in microporous plastic bags resulted in limited respiration increase due to wounding and reduced ethylene production. Treatment was considered to increase the shelf life of the product (Chervin *et al.*, 1992). Nevertheless, the application of irradiation may bring about undesirable biochemical changes. In fact, enzymatic browning may be aggravated by

irradiation treatments, which may alter the permeability of cell compartments favoring contact between PPO and its substrate (Mayer and Harel, 1991).

Apples and pears irradiated as a quarantine treatment showed decreased firmness, which was cultivar dependent, and changes in internal color of 'Gala' and 'Granny Smith' apples (Drake *et al.*, 1999). Endive samples that were irradiated revealed longitudinal internal pink-brown lines, which progressed to the entire vegetables piece becoming pink-brown. In contrast, the cut control discolored only on cut surfaces (Hanotel *et al.*, 1995). Such alterations may be an indication of cell damage, release of PPO and browning in the irradiated endive.

2.3.2 Chemical treatments

Chemical treatment is the treatment done to the fruits in order to inhibit or delay the browning process as the result of action by the PPO and atmosphere which reduce the cosmetic value of the fruits.

2.3.2.1 Edible coating

Edible coating for fresh fruits and vegetables especially in minimally process industry has been studied in enabling to kill the deadly E-coli bacteria and also provides a flavor-boost to food or to the fruits that being processed. Composed of apple puree and oregano oil, which acts as a natural antibacterial agent, the coating shows promise in laboratory studies of becoming a long-lasting, potent alternative to conventional produce washes, according to a team of scientists from the U.S. Department of Agriculture (USDA) and the University of Lleida in Spain. The coating also helps in fighting the bacteria apart from adding flavor. There a lot of edible coating, used in the industry, this is not harming the health of the consumers like the chitosan, which is applied mostly to the mango.

Chitosan, is a naturally abundant polymer of β -(1 \rightarrow 4)-*N*-acetyl-D-glucosamine, is derived from the chitin of shellfish. Chitosan has antimicrobial properties which is the ability to fight the microbes that can cause disease to the crops, is soluble in dilute organic acids and is capable of forming films or membranes. Chitosan is non-toxic, biodegradable, and a naturally occurring product. It has been shown to inhibit enzymatic browning in apple and pear juices (Elizabeth and Diane, 2009). The addition of 200 ppm chitosan to McIntosh apple juice resulted in the inhibition of browning.

Although the mechanisms of chitosan inhibits the browning process here is not really known, its inhibitory effect is probably is a consequence of the ability of the positively charged polymer to adsorb suspended polyphenol oxidase, its substrates, or products.

The chitosan coating had potential inhibitory activity on polyphenol oxidase and peroxidase activity in lychee (*Litchi chinensis* Sonn.) fruit. Chitosan has been shown to improve the storage ability of fruits. Its effectiveness in this respect is therefore thought to be due to the formation of a protective barrier on the surface of fruit, which reduces the supply of oxygen for the enzymatic oxidation of phenolics and reduce the exposed area of the fruits with the air. Chitosan is non-toxic and is biologically safe (Elizabeth and Diane, 2009). Thus, the application of a chitosan coating for the control of browning and quality improvement in fruits and vegetables might be accomplished in combination with other methods such as low temperature and suitable packaging.

2.3.2.2 Anti-browning agents

Several types of chemicals are used in the control of browning, some act as inhibitors of the PPO (Arogba, 1999), others by rendering the medium inadequate for the development of the browning reaction, still others act by reacting with the products of the PPO reaction before these can lead to the formation of the dark pigments which is caused by the oxidation of PPO to *o*-quinone (Figure 2.4).

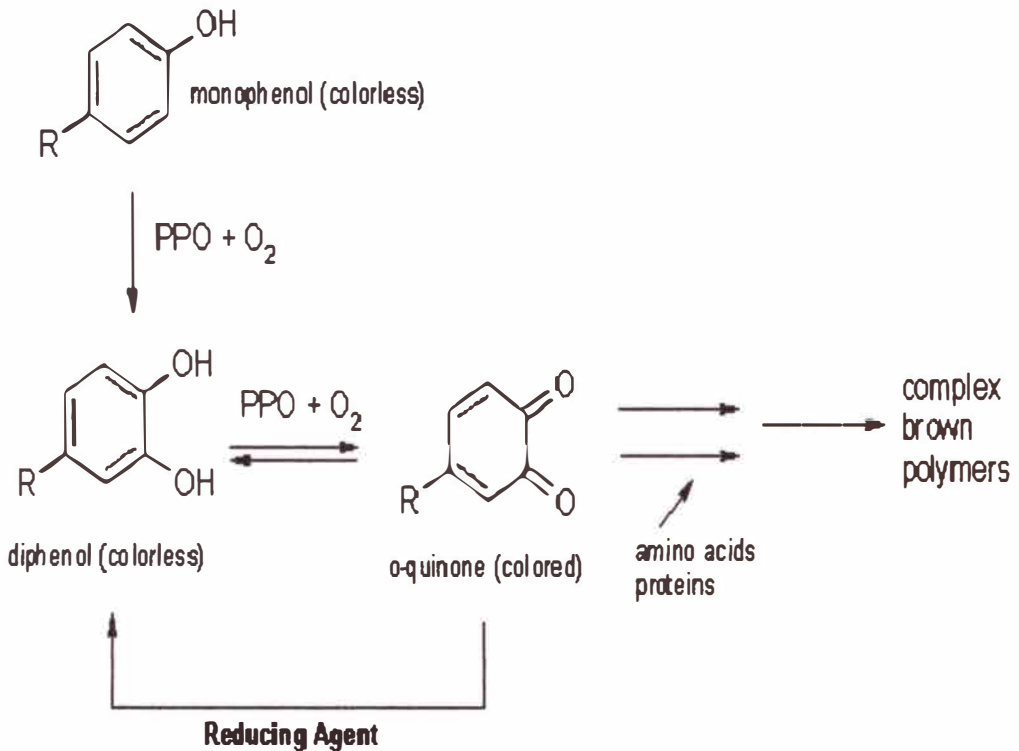


Figure 2.4: The reaction occurs in browning activities.

In general, the use of chemicals in solution forms in order to prevent or to control the enzymatic browning frequently as formulations containing one or more compounds, which are used for dipping the fruits or vegetables pieces. It has been reported that with some chemicals, such as ascorbic and erythorbic acid or their salts, limited penetration into the plant tissue is an issue.

More effective preservation of fresh-cut products can be achieved using a combination of treatments. A common treatment combination includes ascorbic acid and calcium chloride. There are many types of anti-browning;

2.3.2.2.1 Acidulants

While the optimum pH for PPO has been reported as ranging from acid to neutral, in most fruits and vegetables, optimum PPO activity is observed at pH 6.0 – 6.5, while little activity is detected below pH 4.5. It has also reported that irreversible inactivation of PPO can be achieved below pH 3.0 (Richardson and Hyslop, 1985). Nevertheless, it has also been reported that apple PPO is quite tolerant to acidity, and at pH 3.0, it retains 40 % of its maximum activity (Elizabeth and Diane, 2009).

The use of chemicals that lower the product pH, or acidulants, finds widespread application in the control of enzymatic browning. The most commonly used acidulant is citric acid. Citric acid is the one of the most widely used component in the food industry.

It is typically applied at levels ranging between 0.5 and 2% (w/v) for the prevention of browning in fruits and vegetables. In addition, it is often used in combination with other anti-browning agents such as ascorbic or erythorbic acids and their neutral salts, for the chelation of prooxidants and for the inactivation of polyphenol oxidase.

Recommended usage levels for citric acid typically vary between 0.1 and 0.3 percent (w/v) with the appropriate antioxidant at levels ranging between 100 and 200 ppm. Citric acid exerts its inhibitory effect on polyphenol oxidase by lowering

the pH as well as by chelating the copper at the active site of the enzyme (Elizabeth and Diane, 2009).

2.3.2.2.2 Reducing agents

This type of anti-browning agent causes chemical reduction of colorless *o*-quinone resulting from the PPO reaction back to *o*-diphenols (Iyengar and McEvily, 1992). Reductants are irreversibly oxidized during the reaction, which means that the protection they confer is only temporary since they are consumed in the reaction.

When all the reducing agent added is oxidized, the *o*-quinone from the PPO reaction may undergo further oxidation reactions (not involving PPO), and finally rapid polymerization leading to the formation of brown pigments. Due to the oxidative nature of enzymatic reducing agents can also be applied in the prevention of discoloration.

Thiol containing compounds, such as cysteine and glutathione, are also reducing agents that inhibit enzymatic browning. However, for complete browning control the amount of cysteine required (cysteine to phenol ratios above 1) is often incompatible with product taste (Richard-Forget *et al.*, 1992).

Glutathione is a small protein that is composed of three amino acids (cysteine, glutamic acid, and glycine). Glutathione can also be known as GSH. GSH is the smallest intracellular thiol (SH) molecule. Its high electron-donating capacity (high negative redox potential) combined with high intracellular concentration (millimolar levels) generates great reducing power. This gives the ability to the glutathione to reduce the activity of PPO, which will lead to the browning process (Heldt, 2004).

2.3.2.2.3 Chelating agents

By complexing copper from the PPO active site, chelating compounds, such as ethylenediamine tetraacetic acid (EDTA) can inhibit PPO, which is a metalloenzyme containing copper in active site. Sporix is a powerful chelator, and also an acidulant. Browning prevention in apple juice and cut surfaces was obtained with combinations of Sporix and ascorbic acid (Sapers *et al.*, 1989).

2.3.2.2.4 Enzyme inhibitors

One of the anti-browning agents with the most potential for application to fresh-cut products is 4-hexylresorcinol, a chemical that has been safely used in medications for a long time, and has been granted as Generally Recognized As Safe (GRAS) status for use in prevention of shrimp discoloration (melanosis), where it proved to be more effective than sulfite on a weight- to-weight basis (McEvily *et al.*, 1991).

2.3.2.2.5 Other anti-browning agents

Sodium chloride (as other halides) is known to inhibit PPO; its inhibition increases as pH decreases. Chloride is a weak inhibitor; some authors report that the chloride levels required for PPO inhibition are elevated, and may compromise product taste (Mayer and Harel, 1991). Nevertheless, other authors believe that browning control may be possible provided that the dipping solutions are acidic; a pH of at least 3.5 has been suggested (Rout-Mayer and Philippon, 1986).

Calcium treatments used for tissues firming have also been reported to reduce browning (Drake and Spayd, 1983; Hopfinger *et al.*, 1984; Bolin and Huxsoll, 1989). Although citric acid and/or ascorbic acid dips were not effective in preventing

browning of pear, when slices were dipped in 1% CaCl₂ and stored for a week at 2.5°C this resulted in lighter color than water-treated control slices (Rosen and Kader, 1989). In fact, this was most likely due to the PPO inhibition by the chloride ion.

Honey. Anti-browning activity has been attributed to a small peptide isolated from honey. Browning inhibition (62%) in slices of peeled apples has been achieved by dipping in a 10% honey solution for 30 minutes at room temperature. Comparison with a control sucrose solution at the same sugar level as the honey preparation showed only a 23% inhibition of browning (Oszmianski and Lee, 1990).

2.3.2.3 Antimicrobial and sanitizer

There is a natural and effective way to sanitize food without using any toxic chemicals. Treating food with ozone is a very simple and easy way to ensure food safety.

Ozone (O₃) is a form of very reactive oxygen - it kills bacteria by oxidizing them and the only byproducts are water and breathable oxygen. Ozone is approved by the Federal Drug Administration as a proper Antimicrobial agent, and it is 300 to 2000 times more effective than Chlorine at killing microbes.

Eliminate up to 99% of all gut churning bugs, including E.Coli, Salmonella, *Listeria* *Giardia*, fungi, and other sources of food borne illnesses. In addition to killing bacteria, treating food with ozone also breaks down harmful chemicals. Ozone degrades many pesticides and chemical fertilizers into inert components. Many pesticides are suspected carcinogens, so it is important to minimize the exposure.

Chemical fertilizers can also cause serious allergic reactions, but not if they are broken down to their neutral, harmless ingredients. Compare ozone with

chlorine. Chlorine is used in almost every water sanitation plant, and it is very effective at killing waterborne illnesses and fungus. However, chlorine is not very effective at denaturing pesticides and it can produce carcinogenic halides. Chlorine is not very good for the environment either. Producing chlorine is a toxic process, and its byproducts cause secondary pollution.

Ozone, on the other hand, can be made without any mining or refining - it is produced by passing electricity through water. After ozone does its job disinfecting food, it will naturally revert to oxygen without producing any toxic residue. Ozone is the environmentally friendly way to sanitize food (Clean Air Gardening, 2008).

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

3.1.1 Collection of samples

The banana; 'Pisang Awak' or *Musa x paradisiaca* (ABB group) (*cv. awak*) at the indices of 3 and 4 used in this study was obtained from the local suppliers at Pasar Payang, Kuala Terengganu. Actually, the banana imported from Kelantan. The banana was bought for RM 1.50 to RM 2.00 per kilogram.

The prices were verified according to availability and the fruits conditions. Right after bought, the banana was transported to Post Harvest Technology Laboratory for further steps. The total hands of banana used in this experiment were 520. Only the good-looking appearance and healthy bananas were selected for further steps in order to get the best data obtained without any complication.

3.1.2 Reagents and chemicals used in this study

As in the following table;

3.1.2.1 Anti-browning agents

Table 3.1: Anti-browning agents used in this study.

No.	Chemical	Molecular formula	Molecular weight (g/mol)	Characteristics
1.	Anhydrous Citric acid	$C_6H_8O_7$	192.13	- Anhydrous powder
2.	N-acetyl-L-cysteine	$C_5H_9NO_3S$	163.19	- The solubility of this chemical is 100 mg / ml in H_2O with heating
3.	L-Glutathione reduced	$C_{10}H_{17}N_3O_6S$	307.32	- In powder form

All the above anti-browning agents used in this study were food grade and were purchased from R&M Marketing, Essex, United Kingdom.

3.1.2.2 Sanitizer

Sanitizer used in this study was chlorine dioxide release mixture, Scentrex™ DTS.1.05 Sachet that was purchased from Aldrich Chem. Co. The use of this chemical was to prevent and minimize as low as possible as could, the growth of any fungi and bacteria on the surface of the sliced banana. First, the solution was prepared by diluting 0.0005 g of chlorine dioxide into 1 L of distilled water. The method was done by dipping the sliced banana in the chlorine dioxide, which was placed in a clean

container for 2 minutes for each treatment. To minimize the browning activity, some ice with the ratio of distilled water to ice was 2:1.

3.1.2.3 Sterilizer

Sterilizer used in this study was chlorine, $C_3Cl_3N_3O_3$, which is in tablet form. The chlorine was purchased from R&M Marketing with molecular weight of 232.41 g/mol. This chlorine tablet was used to sterilize all the utensils used in this study.

3.1.2.4 Other chemicals / reagents

3.1.2.4.1 Phenolphthalein

Phenolphthalein which is ~1.0% alcoholic solution was used in titration process where 3 drops of the reagents were dropped into the mixture of distilled water and banana juice.

3.1.2.4.2 Sodium hydroxide (NaOH)

The chemical was purchased from R&M Marketing. The molecular weight of this NaOH is 40.00 g/mol.

3.2 Methods

3.2.1 Washing the bananas

Once the banana was dehanded, the fingers of the banana was washed (Figure 3.1) using ice-cooled water in order to remove all the dirt from the peel. This was very important to make sure all the process in this research and the process of preparing the minimally processed sliced banana were in fully sanitized condition. This was to make sure the safety and the quality of the products that are produced meet the standard and the specification according to Food Law and Regulation.



Figure 3.1: Dehanded and washed banana.

3.2.2 Peeling and cutting the bananas

Once all the bananas had been washed, the banana then was peeled and cut into halves using common knife in the laboratory (all the equipments used were sterilized using solution of chlorine and rinse with distilled water). Each of the bananas was 2-2.5 cm in height. All the slices were cut as uniformly as possible for standardization process (Figure 3.2).



Figure 3.2: Cutting the banana for uniform slices.

3.2.3 Sanitizing the slices

All the sliced banana were placed in containers that contained the sanitizer. The sanitizer used in this study was chlorine dioxide. The amount of chlorine dioxide used was 5 mg/L of distilled water. In order to maintain the condition of the slices and to delay the browning process, some ice slurry was added in the chlorine dioxide solution. All the slices were immersed in the solution for approximately 2 minutes. This process done was to make sure the cleanliness and hygiene of the minimally processed banana.

3.2.4 Draining the slices

After the slices were immersed in the sanitizer solution, all the slices were drained using filter in order to remove all the solution. The draining process took about 2 minutes (Figure 3.3).



Figure 3.3: The draining process to remove excess sanitizer solution

3.2.5 Treatment with selected anti-browning agents

All the anti-browning agents as listed in section 3.1.2.1 were prepared according to its particular concentration based on the minimal concentration for an effective anti-browning activity (Son *et al.*, 2007) like in Figure 3.4. The preparation procedures for each anti-browning were detailed as follow;



Figure 3.4: The dipping process using selected anti-browning.

3.2.5.1 Citric acid (0.5 M)

0.5 M Citric acid was prepared by diluting 28.82 g of citric acid with 300 ml of distilled water. The solution was stirred until all the solid compound of citric acid dissolved in the distilled water. The solution was kept in the chiller at $5\pm 1^{\circ}\text{C}$ prior to storage treatment.

3.2.5.2 Glutathione (0.1 M)

0.1 M glutathione was prepared by diluting 9.22 g of the glutathione powder into 300 ml of distilled water. The solution was stirred to make sure that all the solids were dissolved. After that, the solution was kept in the chiller at $5\pm 1^{\circ}\text{C}$ prior to storage treatment.

3.2.5.3 N-acetyl -L-cysteine (0.05 M)

0.05 M N-acetyl-L-cysteine solution was prepared by dissolving 2.45 g of N-acetyl-L-cysteine into 300 ml of distilled water. The solution was stirred to ensure that all N-acetyl-L-cysteine was completely dissolved in the distilled water. After that, the solution was kept in the chiller at $5\pm 1^{\circ}\text{C}$ prior to storage treatment.

3.2.5.4 Combination of citric acid (0.5 M) and glutathione (0.1 M)

For the combination of 2 types of anti-browning agents, the citric acid solution was combined with glutathione solution. The combination was prepared by dissolving 28.82 g of citric acid and 9.22 g of the glutathione powder in 300 ml of distilled water. The solution was stirred in order to make sure all the solid particle to completely

dissolve in the distilled water. After that, the solution was kept in the chiller at $5\pm 1^{\circ}\text{C}$ prior to storage treatment.

3.2.5.5 Combination of citric acid (0.5 M) with N-acetyl-L-cysteine (0.05 M)

The combination was prepared by diluting 28.82 g of citric acid and 2.45 g of N-acetyl-L-cysteine with 300 ml of distilled water. The solution was make sure to be completely dissolve in the distilled water. After that, the solution was kept in the chiller at $5\pm 1^{\circ}\text{C}$ prior to storage treatment.

3.2.5.6 Control (distilled water)

No chemical was used for control treatment. Therefore, the sliced banana was dipped in the distilled water for 2 minutes, as was done in the other treatments.

3.2.6 Draining process

All the sliced bananas that have been dipped in anti-browning agents solutions and distilled water for 2 minutes were then drained using plastic basket as in Figure 3.5 to remove the excess anti-browning agents and distilled water.

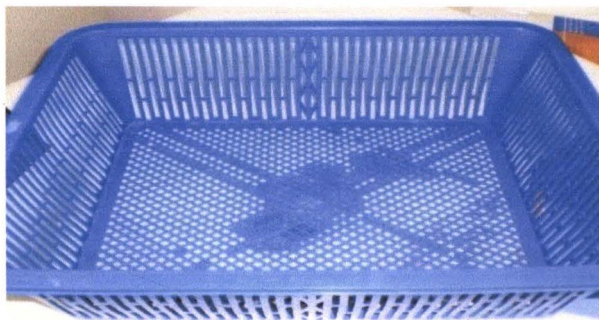


Figure 3.5: The plastic basket used in draining process.

3.2.7 Packaging process

All the treated sliced banana were packed in PP plastic container. One container contained 5 slices of the treated banana as in Figure 3.6.

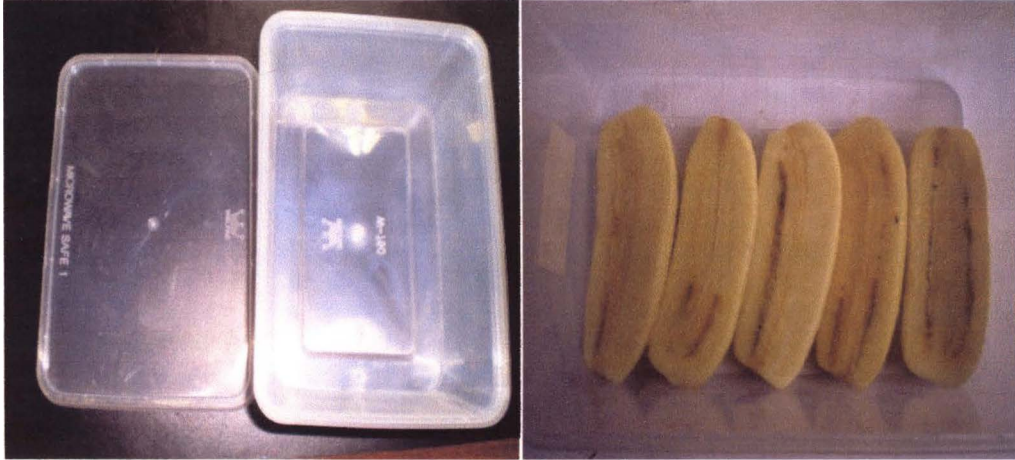


Figure 3.6: PP Plastic container used and one container contained 5 slices of banana.

3.2.8 Storage

All the packed bananas were stored in the chiller at $5\pm 1^{\circ}\text{C}$, RH $90\pm 5\%$. The temperature was daily checked in order to avoid any drastic temperature fluctuation. All the samples were stored for 15 days.

3.2.9 Data evaluation

All the samples were stored in the chiller for 15 days and 3 packs of sliced bananas from each treatment were taken out for analysis at 3 day intervals.

3.2.9.1 Firmness (texture)

3 slices of each replicates in each treatment were measured the firmness or the texture. In this study, the texture of the sliced banana was measured using the

TA.XTplus (Texture analyzer) and the probe used was the blade with knife. Before measuring the firmness of the samples, the TA.XTplus (Texture analyzer) was calibrated. The calibration of height was done to make sure the height between the probe and the samples were at the ideal height. After that, the calibration of force was done to determine the depth, speed and distance of the penetration were at the correct value.

3.2.9.2 Titratable acidity

Titrate acidity analysis was done to measure the percentage of major or dominant acid that exist in the banana, which is malic acid. The methods were as same as the methods in determining the pH value. Ten grams of each replicate from each treatment were blended using the laboratory blender for 2 minutes with 30 ml of distilled water.

Then, the value was made up to 50 ml. After that, 10 ml of the aliquot from the volumetric flask was taken for titrate acidity determination. The evaluation was done 3 times for each replicate. Three drops of phenolphthalein were dropped into the 10 ml juice taken and titrated with 0.1 M NaOH until the solution turned to light pink color.

The next step was the malic acid percentage calculation. The percentage of malic acid was calculated using the following formula;

$$\% \text{ malic acid} = \frac{\text{Titre} \times \text{Normality of alkali} \times \text{volume made up} \times \text{Eq.weight} \times 100}{\text{Volume taken for estimation} \times \text{weight of sample} \times 1000}$$

- Note – miliequivalent weight of organic acid is as follow:

$$\text{Malic acid} = 134 \text{ mg}$$

3.2.9.3 Total color change on back surface and cut surface

The surfaces of the sliced banana, which comprised of 2 major surfaces; the cut surface and the back surface of the sliced banana, was evaluated using the Konica Minolta Chroma Meter (Model Cr-400). Before the data was evaluated, the chromameter was calibrated using the standard white tile provided. Then, both surface color of the sliced banana were taken. Three readings were taken from each of the surface. Meaning that, the cut surface of the sliced banana had 3 reading and the back surface also had 3 readings. The reading of L^* , a^* and b^* were taken. After the data was evaluated, the total color change of the surface's color was calculated using the following formula;

$$\Delta C = [((L_n - L_0)^2 + (a_n - a_0)^2 + (b_n - b_0)^2)]^{1/2}$$

3.2.9.4 pH

pH of the treated sliced banana was taken from each replicates using Metler Toledo pH meter. Before the pH value was taken, the pH meter was calibrated using the buffer solutions provided. The buffer solutions were at pH 4.0 and 7.0. Ten grams of each replicate was blended (using Waring Blender) with 30 ml distilled water for 2 minutes. After that, the juice was poured into measuring cylinder (50 ml) and made up to volume with distilled water. Ten ml of the blended samples was taken for pH determination.

3.2.9.5 Percentage of weight loss

Weight loss of the replicates from each samples were taken every 3 day intervals using the top pan balance (Shimadzu) Model. The percentage of weight loss was calculated using the following equation;

$$\% \text{ of weight loss} = [(\text{Initial weight} - \text{Final weight}) \times 100] / \text{Initial weight}$$

3.2.9.6 Total soluble solid (TSS)


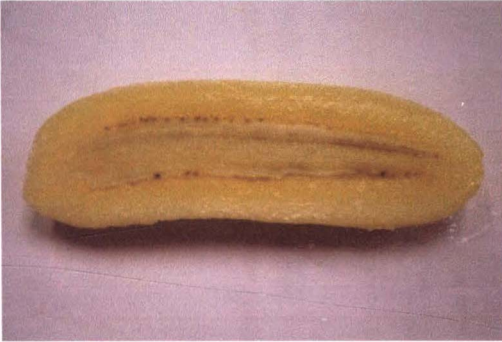
This determination was done to indicate the value of sugar content in the treated sliced banana using the handheld refractometer. The results obtained were expressed in the degree of Brix ($^{\circ}$ Brix). The treated sliced bananas were mashed using mortar and pestle and some drops of the juice produced was filtered using muslin cloth and the juice was dropped onto the refractometer lens. Then, the value was recorded.

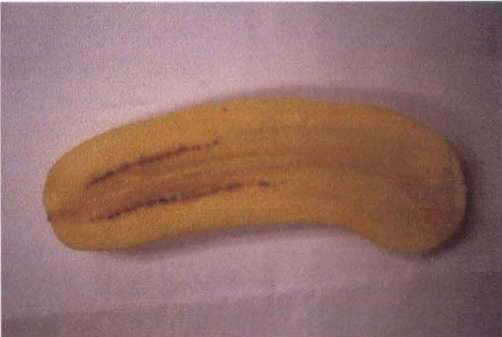
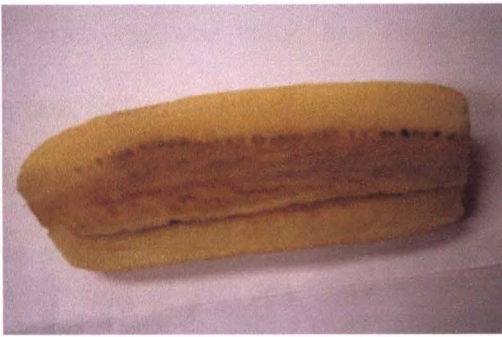
3.2.9.7 Browning index

Browning index is the index made to classify the browning incidence of the treated sliced banana based on the percentage of the surface that had turned to brown. Three packs of sliced bananas for each treatment were taken out from the chiller every 3-day intervals. The samples were left at ambient temperature and the index of the browning of each slices in each container were taken at 30 minutes, 60 minutes and 120 minutes.

The index starting from 0 to 3. The index was scaled according to the following scores (Table 3.1)

Table 3.2: Browning index scores

Score	Pictures
<p><u>Score 0</u></p> <ul style="list-style-type: none">- none of the surface had turn to brown	
<p><u>Score 1</u></p> <ul style="list-style-type: none">- slight- up to 10% infected or had turned to brown	

Score	Pictures
<p><u>Score 2</u></p> <ul style="list-style-type: none">- moderate- 10 – 40% had turned to brown	
<p><u>Score 3</u></p> <ul style="list-style-type: none">- severe to extreme- > 40% had turned to brown	

3.2.9.8 Statistical analysis

The data collected from all the analyses were analyzed using the analyses of variance (ANOVA) significant differences ($P < 0.05$) between treatments were determined using Tukey Test. The statistical programme used was the SPSS.

CHAPTER 4

RESULTS AND DISCUSSIONS

The results obtained throughout the study are discussed as follows;

4.1 Firmness

The treated sliced bananas' firmness was analyzed using the TA.XTplus (Texture Analyzer). Firmness is a very important factor in determining consumers' acceptability of the products. Too tender or too hard the texture of the products, it will indicate the metabolism and water loss of the products during storage. Figure 4.1 shows the firmness of treated sliced bananas which were declining over the storage time.

The results in Figure 4.1, showed that sliced bananas Control and those treated with citric acid (0.5 M) had higher firmness values on day 0. Meanwhile the other 3 treatments which were the combination of citric acid (0.5 M) and glutathione (0.1 M), combination of citric acid (0.5 M) and N-acetylcysteine (0.05 M) and also glutathione (0.1 M) showed firmness values of around 700 g. Another treatment, which was the N-acetylcysteine (0.05 M), showed the least firmness on the day 0.

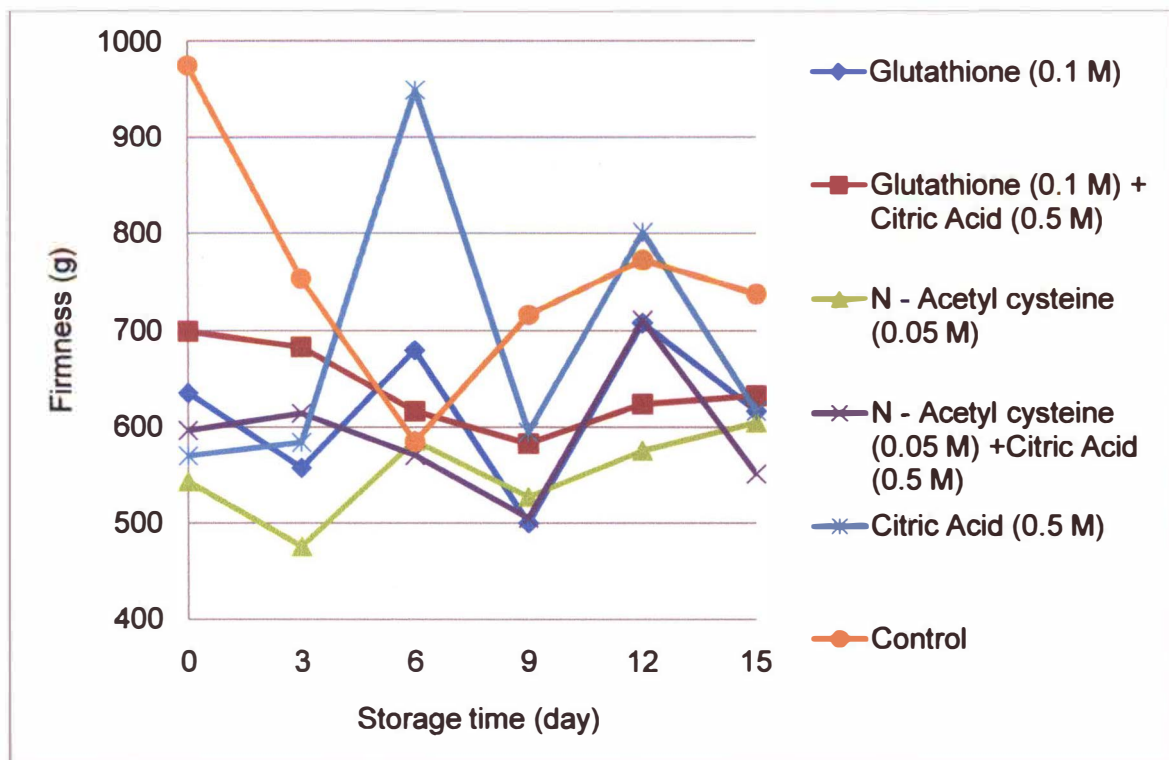


Figure 4.1: The Firmness of sliced bananas treated with different anti-browning agent during low temperature storage

The trends of the firmness values were inconsistent over the 15 days of storage. The firmness on day 15 was not significantly different ($p>0.05$) among all the treatments (Table 4.1). The results also showed that by applying various anti-browning agents on the sliced bananas were not causing the firmness of each treatment to be significantly different among each other on day 3. By applying the various type of anti-browning, the texture or the firmness of the sliced bananas will not change drastically and cause unacceptability by consumers. From Table 1, it can be observed that the firmness of all the treated bananas were not significantly different if compared to each other on each day of storage but were significantly softer compared to Control except on day 6, day 9 and day 15.

The decreasing firmness of each sliced bananas in each treatment used was due to normal cell degradation in the internal cell of the sliced bananas. Softening and texture changes, cutting, peeling and especially, slicing result in dramatic losses in

firmness of fruit tissues. The tendency to soften is dependent on the physiological state. Softening itself is a complex process that includes physiological, enzymatic, chemical and physical changes in the tissues. Pectolytic and proteolytic enzymes exude from the bruised cells and diffuse into inner tissues (Varoquaux *et al.*, 1990).

Sugars and other components diffuse to the intercellular spaces. This causes losses of turgor and softening of the tissues (Poovaiah, 1986; Bolin and Huxsoll, 1989; King and Bolin, 1989). In processed fruit and vegetables softening are also caused by hydrolytic changes of macromolecules under acidic conditions, especially during heating.

Consumers' expectation of the texture is the important benchmark in determining the quality of certain produced. Plant cell constituents that are important in texture are the parenchyma cells, which have the ability to absorb water and generate hydrostatic pressure called turgor pressure. It is the important factor that gives fresh produce its characteristic of crispiness and firm texture. Loss of water from cell of fresh produces due to evaporation can cause loss of firm texture which then followed by breakdown of cell wall composition. According to Harker *et al* (1997), turgor has a major function in determining tissue strength and closely related to the produce texture.

Table 4.1: Effect of anti-browning agents on the firmness of sliced banana

Treatment	Firmness (g)					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Glutathione (0.1 M)	6.35±104.39 ^{Aa}	5.58±58.36 ^{Ab}	6.80±336.51 ^{Aa}	4.99±35.07 ^{Aa}	6.44±208.43 ^{Aa}	6.17±159.25 ^{Aa}
Glutathione (0.1 M) + Citric Acid (0.5 M)	6.99±136.22 ^{Ab}	6.83±141.97 ^{Ab}	6.17±244.60 ^{Aa}	5.83±84.79 ^{Aa}	6.24±21.18 ^{Aa}	6.33±131.22 ^{Aa}
N - Acetyl cysteine (0.05 M)	5.44±66.06 ^{Aa}	4.76±17.61 ^{Aa}	5.86±141.27 ^{Aa}	5.28±191.52 ^{Aa}	5.76±49.79 ^{Aa}	6.05±154.79 ^{Aa}
N - Acetyl cysteine (0.05 M) +Citric Acid (0.5 M)	5.97±109.35 ^{Aa}	6.14±55.58 ^{Ab}	5.71±162.59 ^{Aa}	5.05±40.85 ^{Aa}	7.11±151.95 ^{Aa}	5.52±70.69 ^{Aa}
Citric Acid (0.5 M)	5.70±50.85 ^{Aa}	5.84±51.01 ^{Ab}	9.50±205.01 ^{Ba}	5.95±86.44 ^{Aa}	8.01±69.75 ^{ABa}	6.17±22.48 ^{Aa}
Control	9.75±132.10 ^{Bb}	7.53±51.41 ^{Abb}	5.85±101.97 ^{Aa}	7.16±191.41 ^{ABa}	7.73±96.47 ^{ABa}	7.38±121.90 ^{ABa}

Note: Values in Table 4.1 are mean of 3 replicate (3 representatives) samples / replicate). Mean (n=9) ± 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)

4.2 Titratable acidity

Fresh produce is the most important source of many vitamins in the human diets. Consumers generally regard any fresh produce as being extremely nutritious and far superior to processed products. This belief may not be true, however, since storage conditions; especially storage temperature can have a significant effect on organic acid and other nutrients contents. In banana, the major organic acid is the malic acid.

Figure 4.2 shows the percentage of malic acid of each treated sliced bananas. Titratable acidity was analysed as malic acid i.e the major acid that can be found in bananas and it is very important in determining the sugar level as malic acid will degrade to sugar and give sweeter taste to the sliced bananas (Wills *et al.*, 1981). The results obtained showed that the percentage of malic acid were decreased over the storage time. The degradation process occurs when bananas undergo some biochemical metabolisms as the result of ethylene reaction and respiration.

From Figure 4.2, the trend of the percentage malic acid from day 0 to day 15 in all the treatments were decreasing. The percentage was declining due to degradation of organic acid, mostly malic acid as the dominant acid in banana, had degraded to sugar. The degradation process was due to the metabolism activity as the result of respiration by the banana cell which will consume the malic acid to be converted to sugar. Meanwhile, the decreasing malic acid in sliced bananas that had been treated with glutathione (0.1 M), N-acetylcysteine (0.05 M) and combination of N-acetylcysteine (0.05 M) and citric acid (0.5 M) was not significantly different (Table 4.2) among each other, but also not significant than those bananas treated with glutathione (0.1 M), citric acid (0.5 M) and

Control treatments. The difference was due to different metabolism that occurred on the samples.

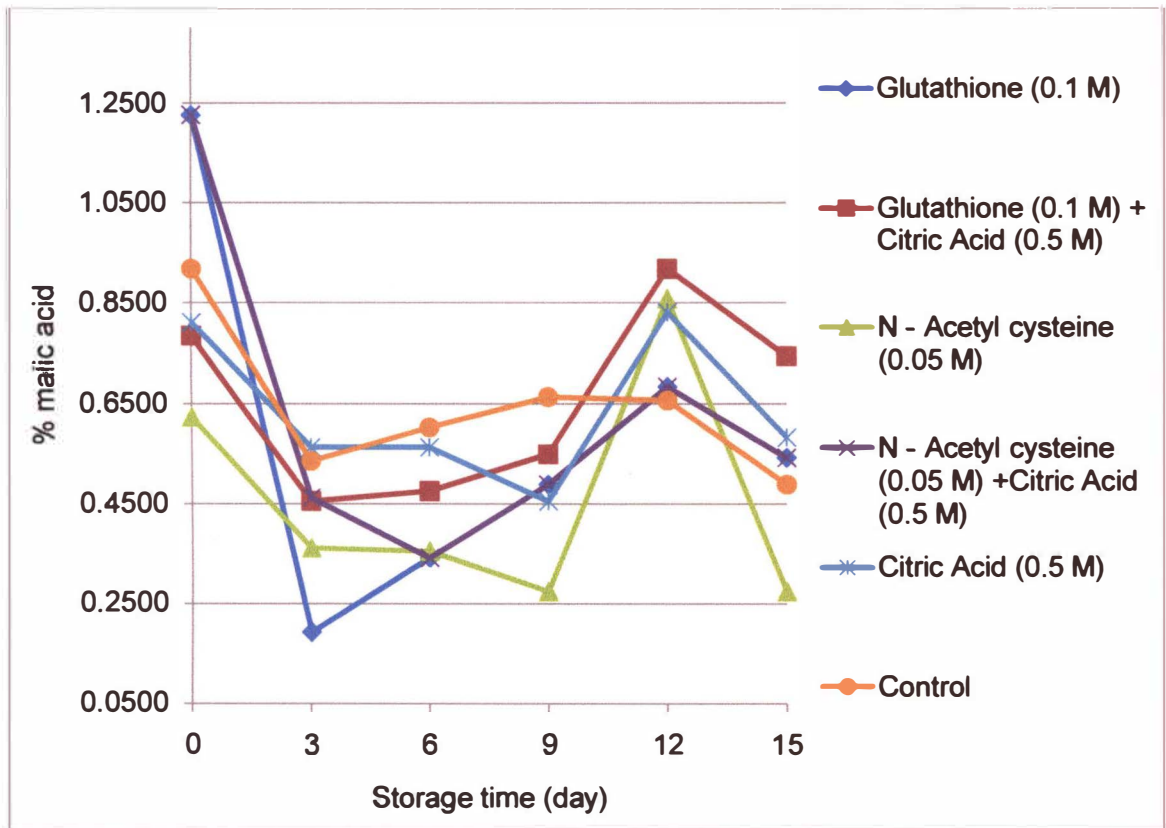


Figure 4.2: The percentage malic acid of sliced bananas treated with different anti-browning agents during low temperature over storage

Most of the treatments showed no significant difference among the treatments throughout the storage time. The percentage of malic acid was not really affected by the treatments because all the treatments were not significantly different.

Table 4.2: Effect of anti-browning agents on the titratable acidity of sliced banana

Treatment	Titratable acidity (mallic acid)					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Glutathione (0.1 M)	12.28±3.17 ^{Ba}	4.62±2.39 ^{Aa}	3.44±0.50 ^{ABb}	4.91±2.71 ^{Aa}	6.83±1.24 ^{ABa}	5.30±0.57 ^{Aa}
Glutathione (0.1 M) + Citric Acid (0.5 M)	7.25±6.05 ^{Aa}	3.26±2.33 ^{Aa}	2.86±1.63 ^{Aa}	4.57±3.61 ^{Aa}	6.56±4.56 ^{Aa}	5.29±3.78 ^{Aa}
N - Acetyl cysteine (0.05 M)	6.25±0.77 ^{Aa}	3.57±0.80 ^{Aa}	3.48±0.12 ^{ABb}	2.75±0.57 ^{Aa}	6.32±4.38 ^{Aa}	2.75±0.12 ^{Aa}
N - Acetyl cysteine (0.05 M) +Citric Acid (0.5 M)	12.28±3.17 ^{Ba}	4.62±2.39 ^{Aa}	3.44±0.50 ^{ABb}	4.91±2.71 ^{Aa}	6.83±1.24 ^{ABa}	5.45±0.66 ^{Aa}
Citric Acid (0.5 M)	8.11±0.57 ^{Ba}	5.65±0.34 ^{Aa}	5.65±0.34 ^{Abc}	4.56±0.68 ^{Aa}	8.29±1.02 ^{Ba}	5.81±0.24 ^{Aa}
Control	9.16±2.92 ^{Aa}	5.36±0.20 ^{Aa}	6.03±1.14 ^{Ac}	6.61±2.11 ^{Aa}	6.54±2.06 ^{Aa}	4.91±2.72 ^{Aa}

Note: Values in Table 4.2 are mean of 3 replicate (3 representatives) samples / replicate). Mean (n=9) ± standard deviation.

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

a-c: Mean bearing the same superscript within the same column are not significantly different at 5% level (p<0.05)

Storage of fruits and other fresh produces also affects the stability of the acid and other nutrient components. The types of acid lost depend on the prior treatment of the produce before storage and storage condition. For example, trimming, dicing, peeling, chopping of fruits before storage can enhance the water soluble vitamins (vitamin C, B-group, E) and acid through leaching during washing and handling (Wills *et al.*, 1981).

4.3 Total color change on back surface and cut surface

A total color change is the parameter that will indicate the overall changes of color that can be detected on the sliced bananas. The total color change can be calculated from L*, a* and b* value. Total color changes on the cut and back surface of the sliced bananas are very important parameter to observe the changes that occur in both sides, whether at the back and cut surface (Figure 4.3 and Figure 4.4).

Figure 4.3 shows the result of total color change on the back surface of the sliced bananas. Total color changes are calculated from L*, a* and b* values. From Figure 4.3, the total color changes gave increasing trend which indicate that there were changes in all the treatments over the storage time. Throughout the storage period, Control showed the greatest total color changes compared to other treatments. This was due to the bananas that had no anti-browning application showed the greatest change in color which totally reduced the quality of the produce. Consumers' acceptability is based on the physical appearance of the products. The back surface of banana slices that had been treated with N-acetylcysteine (0.05 M), glutathione (0.1 M), citric acid (0.5 M) and combination of

glutathione (0.1 M) and citric acid (0.5 M) showed the least changes on the back surface on day 15 compared to Control and N-acetylcysteine (0.05 M).

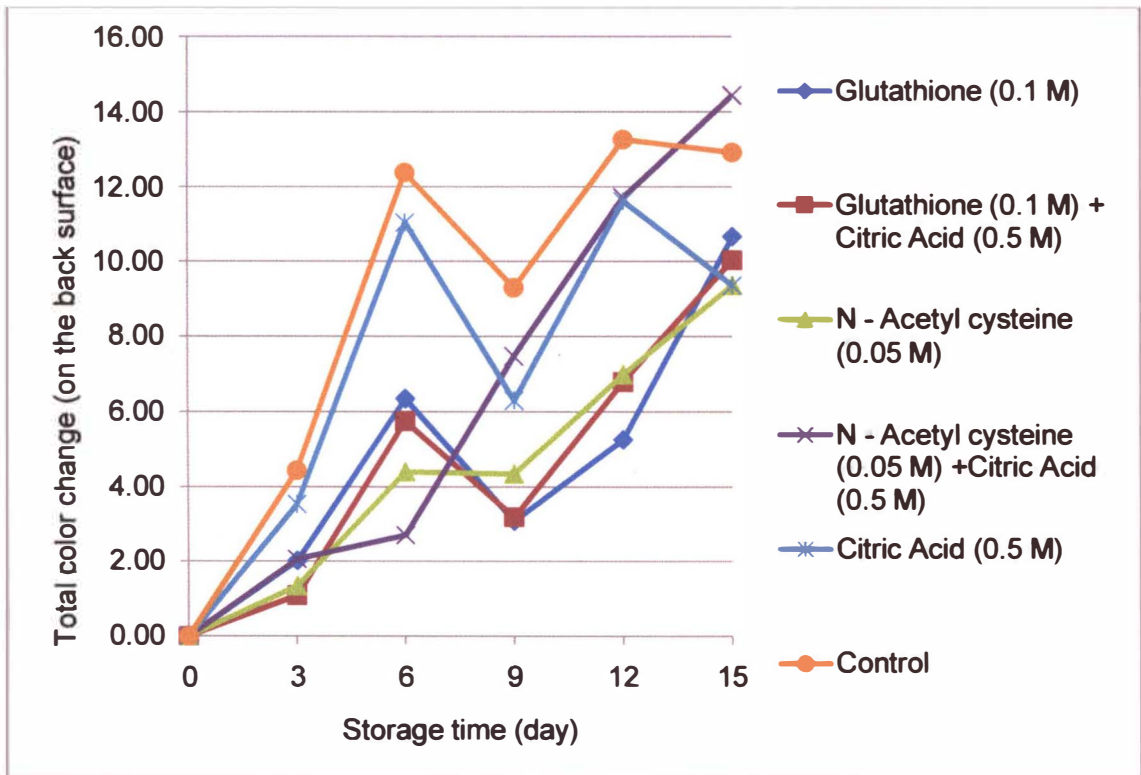


Figure 4.3: The total color change on back surface of sliced bananas treated with different anti-browning agents during low temperature storage

However, the significant different in terms of total color changes cannot be analyzed due to disruptive method of samplings. The statistical analysis of the color can be done according to the L*, a* and b* values (Table 4.3, Table 4.4 and Table 4.5, Table 4.6, Table 4.7 and Table 4.8). The pictures can be seen in Appendix A, Appendix B, Appendix C, Appendix D, Appendix E, and Appendix F.

Table 4.3: Effect of anti-browning agents on the L* value on the cut surface of sliced bananas

Treatments	cut surface L*						
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15	
Glutathione (0.1 M)	79.89±2.41 ^{Aa}	52.04±38.20 ^{Aa}	78.81±0.62 ^{Aab}	74.18±0.84 ^{Aa}	18.67±2.00 ^{Aa}	17.13±0.35 ^{Ab}	
Glutathione (0.1 M) + Citric Acid (0.5 M)	80.98±1.91 ^{Ba}	77.86±2.51 ^{Ba}	76.63±1.37 ^{ABab}	18.84±1.04 ^{ABa}	22.37±3.35 ^{Aa}	16.82±1.06 ^{Ab}	
N - Acetyl cysteine (0.05 M)	79.01±1.55 ^{Ca}	77.16±2.04 ^{BCa}	78.49±3.13 ^{BCb}	18.08±0.92 ^{ABCa}	18.72±0.68 ^{ABa}	17.09±0.35 ^{Ab}	
N - Acetyl cysteine (0.05 M) + Citric Acid (0.5 M)	81.11±1.54 ^{Ca}	77.67±1.07 ^{BCa}	77.30±1.08 ^{BCab}	17.60±0.89 ^{ABa}	18.98±0.91 ^{ABa}	16.20±1.22 ^{Ab}	
Citric Acid (0.5 M)	78.65±2.06 ^{Ba}	75.28±3.27 ^{ABa}	73.32±0.96 ^{ABa}	17.12±0.93 ^{ABa}	20.63±0.94 ^{Aa}	17.16±0.43 ^{Ab}	
Control	76.77±1.59 ^{Ca}	69.19±1.11 ^{ABCa}	72.87±2.15 ^{BCa}	22.06±1.01 ^{ABCa}	21.10±1.99 ^{ABa}	21.09±1.82 ^{Aa}	

Note: Values in Table 4.3 are mean of 3 replicate (3 representatives) samples / replicate). Mean (n=9) ± 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 4.4: Effect of anti-browning agents on the b* value on the cut surface of sliced bananas

Treatment	Cut surface b*					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Glutathione (0.1 M)	21.53±1.07 ^{Ba}	21.42±0.25 ^{Bb}	16.52±0.69 ^{Aa}	19.02±1.02 ^{ABb}	19.11±1.67 ^{ABa}	18.18±1.32 ^{ABb}
Glutathione (0.1 M) + Citric Acid (0.5 M)	20.96±1.84 ^{Aa}	21.12±0.67 ^{ABb}	17.04±2.17 ^{Aa}	19.37±0.76 ^{Ab}	20.79±1.95 ^{Aa}	17.59±0.77 ^{ABb}
N - Acetyl cysteine (0.05 M)	22.24±2.10 ^{Ba}	19.90±0.63 ^{ABab}	17.27±1.41 ^{Aa}	18.37±0.21 ^{ABb}	19.01±1.46 ^{ABa}	17.82±0.43 ^{ABb}
N - Acetyl cysteine (0.05 M) +Citric Acid (0.5 M)	20.15±0.70 ^{Ba}	19.89±0.19 ^{ABab}	17.63±2.06 ^{ABa}	17.29±0.29 ^{ABab}	18.61±0.99 ^{ABa}	17.03±1.01 ^{ABb}
Citric Acid (0.5 M)	20.28±1.78 ^{Aa}	18.83±1.99 ^{ABb}	17.53±3.90 ^{Aa}	16.37±1.60 ^{Aa}	19.27±1.34 ^{Aa}	16.55±0.35 ^{Aa}
Control	19.85±0.52 ^{Aa}	18.45±1.05 ^{Aa}	18.33±2.13 ^{Aa}	19.58±0.62 ^{Ab}	19.46±1.08 ^{Aa}	18.75±0.11 ^{Ab}

Note: Values in Table 4.4 are mean of 3 replicate (3 representatives) samples / replicate). Mean (n=9) ± 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 4.5: Effect of anti-browning agents on the a* value on the cut surface of sliced bananas

Treatment	cut surface a*					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Glutathione (0.1 M)	0.80±0.98 ^{Aa}	2.01±1.19 ^{ABa}	1.84±0.56 ^{ABabc}	2.64±0.42 ^{ABa}	2.63±3.03 ^{ABa}	4.77±0.51 ^{Bab}
Glutathione (0.1 M) + Citric Acid (0.5M)	0.41±0.26 ^{Aa}	1.50±0.76 ^{ABa}	1.34±0.40 ^{ABabc}	3.13±0.30 ^{BCa}	4.53±1.53 ^{Ca}	3.72±0.81 ^{Ca}
N - Acetyl cysteine (0.05 M)	1.07±0.46 ^{ABa}	1.88±0.65 ^{ABa}	0.89±0.27 ^{ABb}	2.48±0.92 ^{Ba}	2.18±0.49 ^{ABa}	5.48±0.25 ^{Cab}
N - Acetyl cysteine (0.05 M) +Citric Acid (0.5 M)	0.65±0.70 ^{Aa}	1.94±0.49 ^{ABa}	0.82±0.30 ^{ABa}	3.07±0.82 ^{Ba}	2.39±1.33 ^{ABa}	3.16±1.31 ^{Ba}
Citric Acid (0.5 M)	1.14±0.40 ^{Aa}	2.64±1.14 ^{ABab}	3.13±1.30 ^{ABabc}	2.69±0.89 ^{ABa}	3.05±0.60 ^{ABa}	4.21±0.69 ^{Ba}
Control	2.54±0.34 ^{Ab}	4.83±0.88 ^{ABCb}	3.36±1.38 ^{ABc}	5.63±0.56 ^{BCb}	3.98±0.62 ^{ABa}	6.70±1.28 ^{Cb}

Note: Values in Table 4.5 are mean of 3 replicate (3 representatives) samples / replicate). Mean (n=9) ± 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: Mean bearing the same superscript within the same column are not significantly different at 5% level (p<0.05)

Table 4.6: Effect of anti-browning agents on the L* value on the back surface of sliced bananas

Treatment	Back surface L*					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Glutathione (0.1 M)	78.60±0.78 ^{BCa}	80.36±1.76 ^{Ca}	70.88±1.83 ^{Aa}	76.65±4.13 ^{ABCa}	73.47±3.40 ^{ABa}	69.12±1.01 ^{Aa}
Glutathione (0.1 M) + Citric Acid (0.5 M)	79.60±0.81 ^{Ca}	78.67±1.72 ^{Ca}	72.19±2.42 ^{ABa}	76.79±1.58 ^{B^UCa}	71.43±3.02 ^{Aa}	70.34±1.23 ^{Aa}
N - Acetyl cysteine (0.05 M)	80.98±1.82 ^{Ba}	79.92±1.29 ^{Ba}	69.78±2.66 ^{Aa}	77.10±3.93 ^{ABa}	72.22±1.35 ^{ABa}	72.70±6.38 ^{ABa}
N - Acetyl cysteine (0.05 M) +Citric Acid (0.5 M)	82.40±2.12 ^{Ua}	80.34±0.44 ^{Ua}	70.70±2.37 ^{ABa}	75.29±0.97 ^{B^UCa}	73.15±4.11 ^{ABa}	68.51±0.63 ^{Aa}
Citric Acid (0.5 M)	80.48±1.29 ^{Ba}	77.53±1.34 ^{ABa}	69.45±6.41 ^{Aa}	75.65±1.02 ^{ABa}	73.63±2.77 ^{ABa}	72.35±0.60 ^{Aa}
Control	81.37±1.66 ^{Ua}	77.47±1.44 ^{Ca}	71.69±0.39 ^{ABa}	73.05±1.11 ^{B^Ua}	68.81±1.27 ^{Aa}	69.21±1.59 ^{Aa}

Note: Values in Table 4.6 are mean of 3 replicate (3 representatives) samples / replicate). Mean (n=9) ± standard deviation.

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

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

Table 4.7: Effect of anti-browning agents on the b* value on the back surface of sliced bananas

Treatment	Back surface b*					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Glutathione (0.1 M)	19.22±0.72 ^{BCa}	20.21±0.55 ^{Ca}	16.30±0.98 ^{Aa}	18.93±0.84 ^{ABCa}	18.67±2.00 ^{ABCa}	17.13±0.35 ^{ABa}
Glutathione (0.1 M) + Citric Acid (0.5 M)	20.13±0.03 ^{ABa}	19.64±0.84 ^{ABa}	17.86±1.19 ^{Aa}	18.84±1.04 ^{ABa}	22.37±3.35 ^{Ba}	16.82±1.06 ^{Aa}
N - Acetyl cysteine (0.05 M)	20.89±1.18 ^{La}	20.01±0.48 ^{LUa}	16.46±0.74 ^{Aa}	18.08±0.92 ^{ABCa}	18.72±0.68 ^{BCa}	17.09±0.35 ^{ABa}
N - Acetyl cysteine (0.05 M) +Citric Acid (0.5 M)	19.79±1.03 ^{Ca}	19.09±0.89 ^{BCa}	16.83±1.05 ^{ABa}	17.60±0.89 ^{ABCa}	18.98±0.91 ^{BCa}	16.20±1.22 ^{Aa}
Citric Acid (0.5 M)	20.62±0.94 ^{Ca}	19.45±1.08 ^{BCa}	16.05±2.29 ^{Aa}	17.12±0.93 ^{ABa}	20.63±0.94 ^{Ca}	17.16±0.43 ^{ABa}
Control	19.39±1.15 ^{Aa}	20.30±2.39 ^{Aa}	19.34±0.96 ^{Aa}	22.06±1.01 ^{Aa}	21.10±1.99 ^{Aa}	21.09±1.82 ^{Ab}

Note: Values in Table 4.7 are mean of 3 replicate (3 representatives) samples / replicate). Mean (n=9) ± 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)

Table 4.8: Effect of anti-browning agents on the a* value on the back surface of sliced bananas

Treatment	Back surface a*						
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15	
Glutathione (0.1 M)	-0.74±0.29 ^{Aa}	-0.68±0.15 ^{Aa}	-0.34±0.42 ^{Aa}	0.13±0.13 ^{Aa}	0.35±1.50 ^{Aa}	2.52±0.67 ^{Bab}	
Glutathione (0.1 M) + Citric Acid (0.5 M)	-0.77±0.36 ^{Aa}	-0.47±0.07 ^{Aa}	-0.06±0.25 ^{Aa}	0.01±0.50 ^{Aa}	2.14±2.50 ^{Aa}	1.24±0.51 ^{Aa}	
N - Acetyl cysteine (0.05 M)	-0.58±0.26 ^{Aa}	-0.65±0.18 ^{Aa}	-0.16±0.75 ^{Aa}	-0.04±0.41 ^{Aa}	-0.37±0.22 ^{Aa}	1.55±0.72 ^{Bab}	
N - Acetyl cysteine (0.05 M) +Citric Acid (0.5 M)	-0.72±0.25 ^{Aa}	-0.61±0.26 ^{Aa}	-0.60±0.16 ^{Aa}	-0.04±0.20 ^{ABa}	0.37±0.49 ^{ABa}	0.89±0.73 ^{Ba}	
Citric Acid (0.5 M)	-0.65±0.31 ^{Aa}	-0.22±0.32 ^{ABa}	1.78±1.21 ^{Ca}	0.05±0.34 ^{ABCa}	0.54±0.42 ^{ABCa}	1.24±0.94 ^{BaCa}	
Control	0.27±0.46 ^{Ab}	2.19±0.82 ^{ABb}	0.79±1.57 ^{ABb}	3.46±1.32 ^{ABb}	1.55±1.05 ^{ABa}	4.31±2.05 ^{Bb}	

Note: Values in Table 4.8 are mean of 3 replicate (3 representatives) samples / replicate). Mean (n=9) ± 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 column are not significantly different at 5% level (p<0.05)

According to Table 4.6, Table 4.7 and Table 4.8, there was no significant different in term of L* value on day 0 until day 15 in all the treatments. L* value is one of the factors that will determine the lightness of the produces. However there were not significant of a* values throughout the storage in all the treatments compared to Control. This indicating that the control had not undergone some color changes statistically which might due to enzymatic browning. Same goes to the Control on day 9. The values of b* were increasing and not significant in Control if compared to the other treatments.

The total color changes on back surface of the banana slices are less than those stated on Figure 4.4. Figure 4.4 shows the total color change on the cut surface of the sliced banana. The sliced bananas showed greater total color changes on the cut surface if compared to back surface. This is due to the phenolic reaction is greater on the surface of the fruits that has been cut or slice. This will provide more enzymes and substrate to react to produce *o-quinone* which results in browning color on the surface of the produces. As more cells are not decompartmentalized, the cells are more susceptible to the reaction as the larger surface area will be provided for the enzymatic reaction.

From the Figure 4.4, the trends of the total color changes on cut surface of the sliced banana were increasing over the storage time. As the total color change on the back surface of sliced bananas, Control showed the greatest color changes. This was due to there was no anti-browning agents applied to the sliced bananas and this promoted the enzymatic reaction to occur simultaneously and cause the most color change to the cut surface of Control.

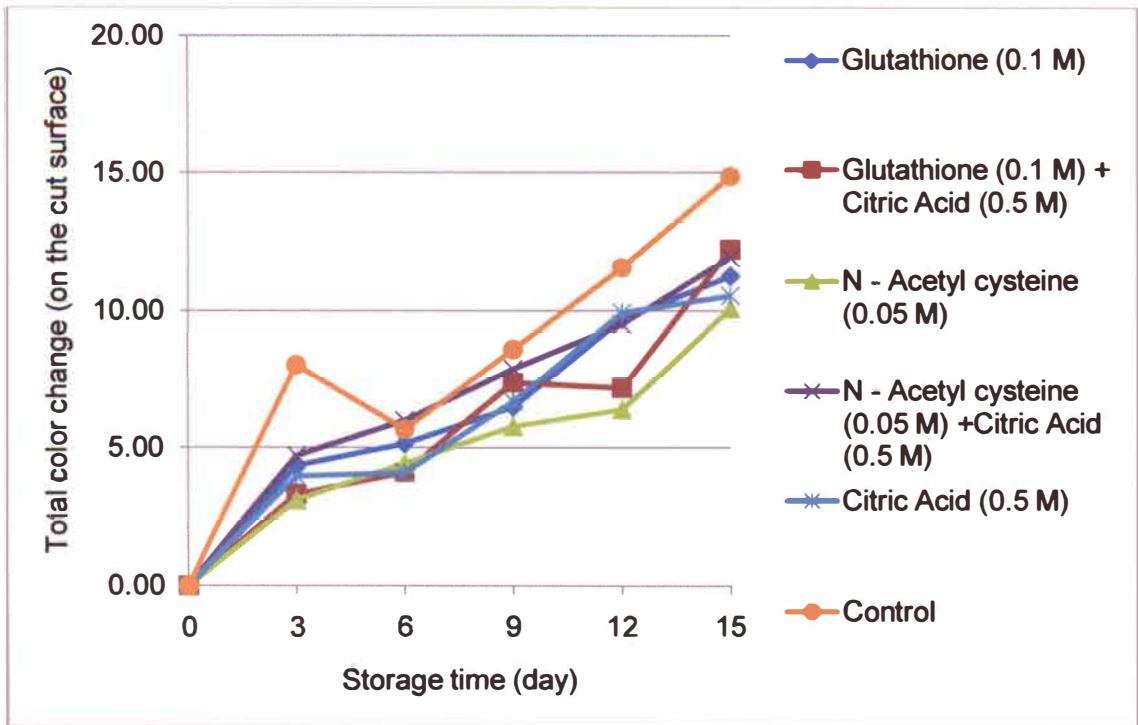


Figure 4.4: The total color change on cut surface of sliced bananas treated with different anti-browning agents during low temperature storage

The statistical analysis done based on the L^* , a^* and b^* values showed in Table 4.3, Table 4.4 and Table 4.5, that there was no significant different on day 0 to day 3 of storage in term of L^* value. But there was significant different on day 6 between treatments. N-acetylcysteine (0.05 M) showed the greatest L^* value change and it is significantly higher if compared to the other treatments. Same happened on day 9 where the changes of L^* value in sliced bananas that were treated with N-acetylcysteine (0.05 M) and Control showed the highest changes and they are significantly different to the other treatments. On day 12, the N-acetylcysteine (0.05 M), combination of N-acetylcysteine (0.05 M) and citric acid (0.5 M) and Control showed some changes and

they are not significant to the other treatments. On day 15, there is no significant different among all the treatments.

4.4 pH

pH indicates that the existence of organic acid that contained in the sliced bananas which can be degraded to sugar. Higher or lower the pH indicates the taste of the sliced bananas whether sour or have any unaccepted taste due to changes in the pH.

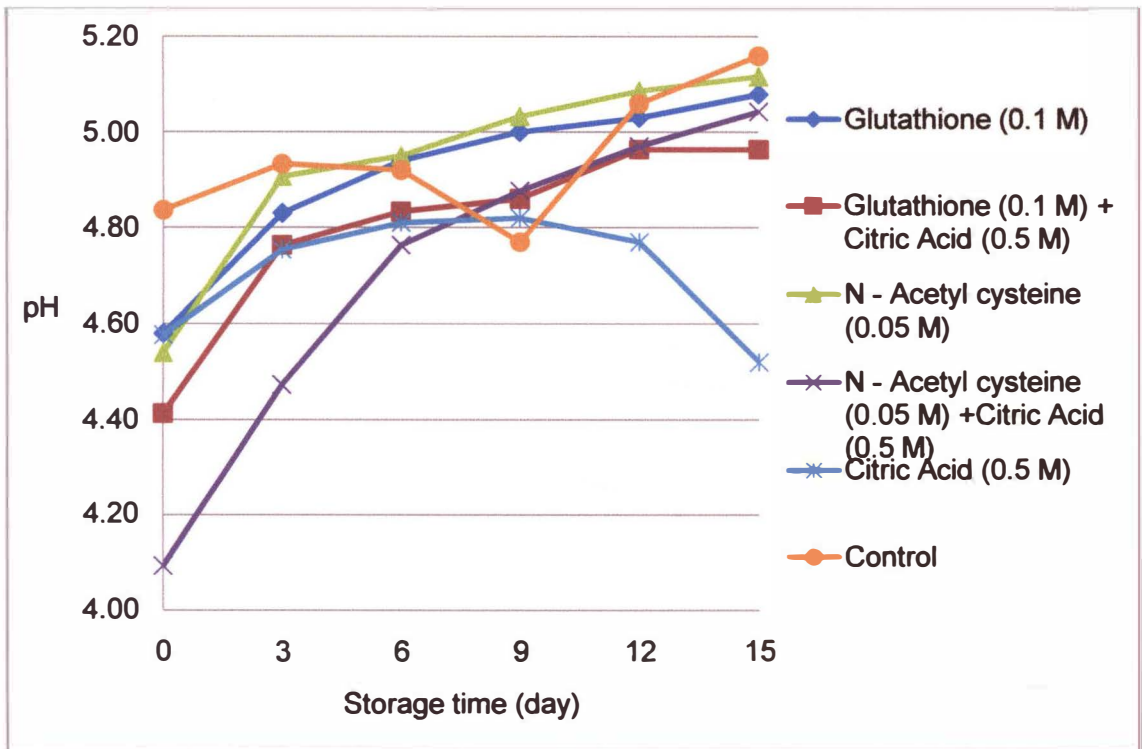


Figure 4.5: pH changes of sliced bananas with different anti-browning agents during low temperature storage

From the Figure 4.5, the trends of pH value in certain treatments were increasing until day 15. But some of the treatments showed increasing and at the last day of storage, which was at the day 12 and day 15, the pH value decreased. For example citric acid (0.5 M) treatment showed increasing pH value but decreased on day 12 and 15. For glutathione (0.1 M), N-acetylcysteine (0.05 M), citric acid (0.5 M), combination of glutathione (0.1 M) and citric acid (0.5 M) and combination of N-acetylcysteine (0.05 M) and citric acid (0.5 M) showed increasing oh pH value started from day 0 to day 15. There was significant different among all the treatments throughout the storage (Table 4.9). But there were not significant pH in Control compared to glutathione, N-acetylcysteine (0.05 M) and combination of N-acetylcysteine (0.05 M) and citric acid (0.5 M) on day 15. Control showed the highest mean of pH value on day 0 and day 9 and it was not significant among other treatments.

This is due to physiological and biochemical degradation that occurs in the sliced bananas which were not treated using any anti-browning agents. The increasing pH value in Control's samples was due to rapid degradation of organic acid which is the malic acid and starch to produce sugar. Thus increasing the pH values. High respiration rate also causes high oxygen admission in tissue and this may be the other reason for increasing TA (Chuenboonngarm *et al.*, 2007).

Table 4.9: Effect of anti-browning agents on the pH of sliced bananas

Treatment	pH					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Glutathione (0.1 M)	4.58±0.01 ^{Ac}	4.97±0.11 ^{Bcb}	4.83±0.05 ^{Bab}	4.94±0.06 ^{BCab}	5.03±0.11 ^{BCb}	5.08±0.12 ^{Cc}
Glutathione (0.1 M) + Citric Acid (0.5 M)	4.41±0.02 ^{AD}	4.76±0.07 ^{BAb}	4.83±0.11 ^{B¹Cab}	4.86±0.10 ^{B¹Ca}	4.96±0.02 ^{Cab}	4.96±0.06 ^{Ubc}
N - Acetyl cysteine (0.05 M)	4.54±0.01 ^{Ac}	4.91±0.02 ^{BAb}	4.95±0.05 ^{Bb}	5.03±0.09 ^{Bbc}	5.09±0.16 ^{Bb}	5.12±0.12 ^{Bc}
N - Acetyl cysteine (0.05 M) +Citric Acid (0.5 M)	4.09±0.02 ^{Aa}	4.47±0.39 ^{ABa}	4.76±0.06 ^{B¹Ca}	4.88±0.06 ^{B¹Cab}	4.97±0.09 ^{Cab}	5.04±0.07 ^{Uc}
Citric Acid (0.5 M)	4.58±0.03 ^{Bc}	4.75±0.03 ^{Cab}	4.81±0.01 ^{Dab}	4.82±0.01 ^{Da}	4.77±0.01 ^{CDa}	4.52±0.01 ^{Aa}
Control	4.84±0.02 ^{Bd}	4.93±0.02 ^{Cb}	4.91±0.01 ^{Cab}	5.16±0.01 ^{Ec}	5.06±0.01 ^{D¹b}	4.77±0.00 ^{Ab}

Note: Values in Table 4.9 are mean of 3 replicate (3 representatives) samples / replicate). Mean (n=9) ± standard deviation.

A- E: Means bearing the same superscript within the same row are not significantly different at 5% level (p<0.05)

a-d: Means bearing the same superscript within the same column are not significantly different at 5% level (p<0.05)

4.5 Percentage of weight loss

Determination of weight loss percentage is very important in determining the moisture loss from the sliced bananas. Moisture or water content in certain produces especially for the minimally processed produces will influence the texture, taste, color and physical appearances of the products. If more water or moisture losses from the products, the taste will be sweeter as the sugar concentration is saturated. It also can affect the texture. If the products loss too much moisture, it will cause the firmness of the products and if less moisture losses, it will cause products to be too tender as all the cells has lysed. Too high or too low percentage of water loss from the products, it will affect the quality of the products. The weight loss percentage of sliced bananas was presented in Figure 4.6.

From the Figure 19, the trend of percentages of weight loss were increasing over the storage time for all the treatments. The moisture loss was due to the evaporation of water from the containers that were stored in chiller at $5\pm 1^{\circ}\text{C}$ and RH at 90 – 95%. On day 3 and day 15, combination of citric acid (0.5 M) and N-acetylcysteine (0.05 M) showed the highest percentage of weight loss in comparison with the other treatments. However, the least percentage of weight loss was showed by N-acetylcysteine (0.05 M). Meanwhile, on day 15, glutathione (0.1 M), N-acetylcysteine (0.05 M) and citric acid (0.5 M) was not significantly different where these three treatments were not too much different if compared to the other treatments.

Table 4.10: Effect of anti-browning agents on the percentage of weight loss of sliced banana

Treatment	Percentage of weight loss (kg)						
	day 0	day 3	day 6	day 9	day 12	day 15	
Glutathione (0.1 M)	0±0 ^{Aa}	0.10±0.09 ^{Aa}	0.24±0.07 ^{ABa}	0.26±0.06 ^{ABa}	0.50±0.28 ^{BCa}	0.63±0.10 ^{Ca}	
Glutathione (0.1 M) + Citric Acid (0.5 M)	0±0 ^{Aa}	0.32±0.14 ^{Aa}	0.60±0.85 ^{Aa}	0.19±0.09 ^{Aa}	0.23±0.07 ^{Aa}	0.28±0.15 ^{Aa}	
N - Acetyl cysteine (0.05 M)	0±0 ^{Aa}	0.29±0.65 ^{BCa}	0.15±0.04 ^{Ba}	0.27±0.05 ^{BCa}	0.37±0.08 ^{Ca}	0.32±0.05 ^{Ca}	
N - Acetyl cysteine (0.05 M) +Citric Acid (0.5 M)	0±0 ^{Aa}	0.24±0.10 ^{ABa}	0.29±0.20 ^{ABa}	0.38±0.25 ^{ABa}	0.58±0.21 ^{Ba}	0.71±0.26 ^{Ba}	
Citric Acid (0.5 M)	0±0 ^{Aa}	0.13±0.03 ^{ABa}	0.28±0.13 ^{ABCa}	0.40±0.12 ^{BCa}	0.50±0.19 ^{BCa}	0.58±0.23 ^{Ca}	
Control	0±0 ^{Aa}	0.16±0.45 ^{ABa}	0.33±0.35 ^{ABa}	0.44±0.08 ^{Ba}	0.45±0.17 ^{Ba}	0.53±0.25 ^{Ba}	

Note: Values in Table 4.10 are mean of 3 replicate (3 representatives) samples / replicate). Mean (n=9) ± standard deviation.

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

a :Mean bearing the same column are not significantly different at 5% level (p<0.05)

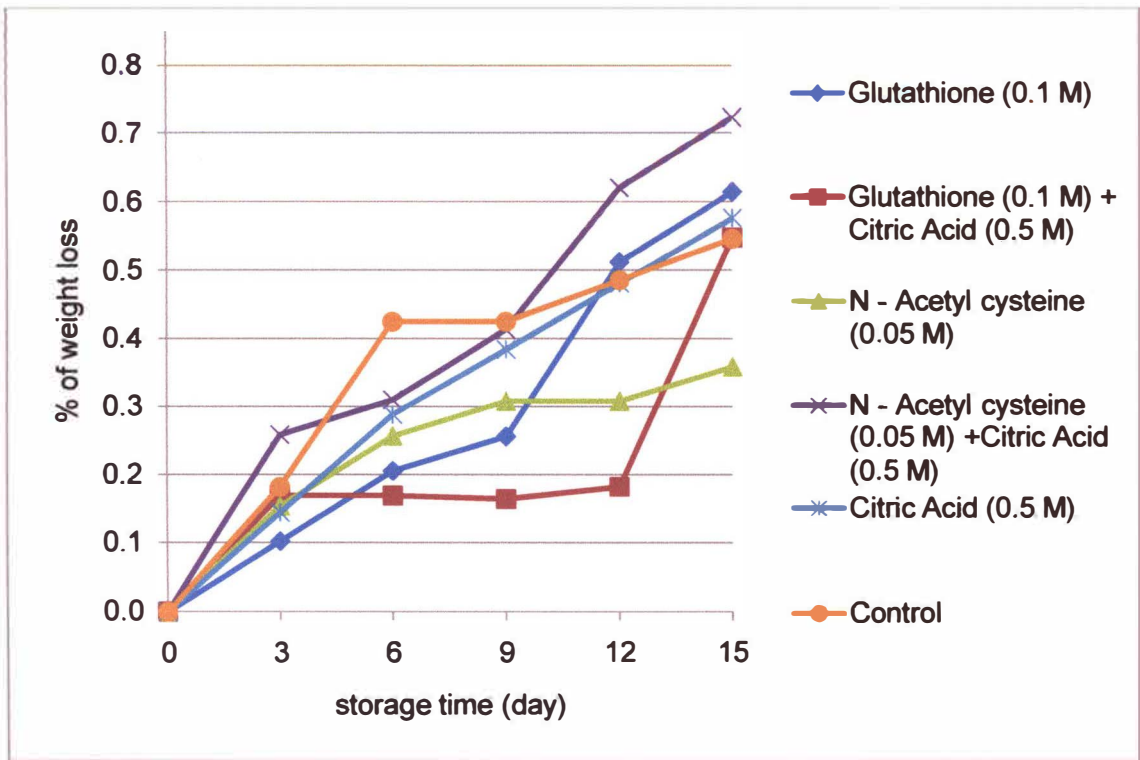


Figure 4.6: The percentage of weight loss of sliced bananas with different anti-browning agents during low temperature storage over storage time

From Figure 4.6, the trends of combination treatment, which was the combination of glutathione (0.1 M) and citric acid (0.5 M) showed least percentage of weight loss in each 3-day intervals, but had a magnificent loss in weight at the last day of storage. However, this result was not significantly different statistically. This means that there was no significant different among the percentage of weight loss observed on each 3-day intervals of the sliced bananas treated with this combination.

The loss of weight was mostly related to the loss of moisture in the sliced bananas cells. This due to the evaporation that occurred on the surface of the slices. Weight loss

can reduce the quality of the minimally processed products as the loss in moisture or water content will lead to other degradation in terms of nutritional and physical appearances.

4.6 Total soluble solid (TSS)

Total soluble solid is a measurement used to indicate the content of soluble solid in the produces, mostly the content of sugar. This measurement is important to determine the level of sweetness as the result of organic acid degradation to produce sugar which gives the sweet taste in certain produces. The level of total soluble solid in treated sliced bananas as in Figure 4.7.

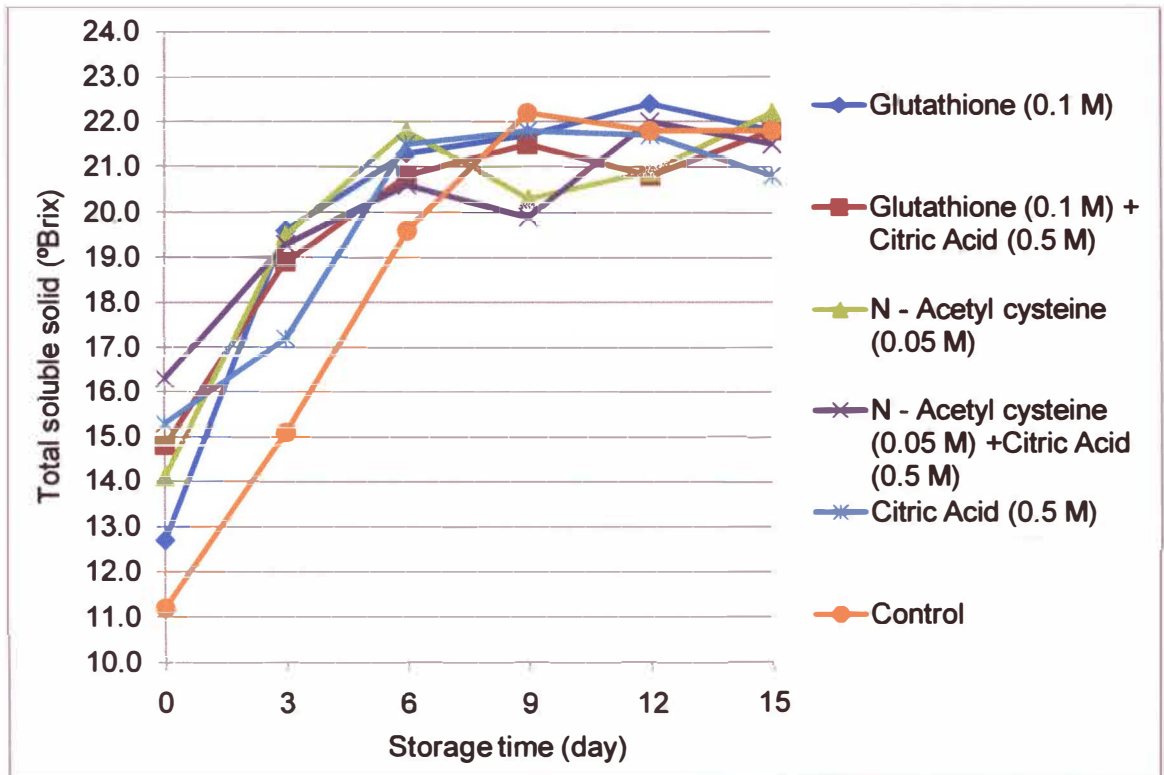


Figure 4.7: The total soluble solid of sliced bananas treated with different anti-browning agents during low temperature storage

From the Figure above, the trends of the TSS were increasing over the storage time. On day 0, the level of total soluble solid in Control has the least level. This indicating that the samples were less sweet if compared to the other treatments. However, N-acetylcysteine (0.05 M) showed the highest TSS value if compared to the other treatments. However, this can be showed by Table 4.11 which showed that there was not significant of TSS value in combination of N-acetylcysteine (0.05 M) and citric acid (0.5 M) as compared to Control on day 0. On day 15, there was no significantly different of Control among the other treatments.

The value of TSS was determined by the conversion or degradation of organic acid and starch to sugar in certain biochemical changes in the cell during storage. The conversion will rise up the level of sugar and give rise to the sweetness.

Table 4.11: Effect of anti-browning agents on the Total Soluble Solid of sliced banana

Treatment	Total soluble solid						
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15	
Glutathione (0.1 M)	12.67±2.35 ^{Aab}	19.57±1.40 ^{Bb}	21.33±0.35 ^{Ba}	21.67±0.58 ^{Bbc}	22.43±0.51 ^{Ba}	21.77±1.08 ^{Ba}	
Glutathione (0.1 M) + Citric Acid (0.5 M)	14.77±1.50 ^{Aab}	18.90±0.85 ^{bb}	20.77±1.36 ^{Ba}	21.47±0.40 ^{Bbc}	20.77±0.68 ^{Ba}	21.80±2.01 ^{Ba}	
N - Acetyl cysteine (0.05 M)	14.10±2.03 ^{Aab}	19.47±0.68 ^{bb}	21.77±0.12 ^{Ba}	20.33±0.91 ^{Bab}	20.90±1.15 ^{Ba}	22.23±0.50 ^{Ba}	
N - Acetyl cysteine (0.05 M) + Citric Acid (0.5 M)	16.33±1.82 ^{Ab}	19.33±1.42 ^{bb}	20.57±0.23 ^{Ba}	19.87±0.51 ^{Ba}	21.97±0.58 ^{Ba}	21.53±0.40 ^{Ba}	
Citric Acid (0.5 M)	15.33±1.80 ^{Aab}	17.23±2.25 ^{AHAb}	21.53±1.66 ^{Ba}	21.77±0.50 ^{Cbc}	21.67±1.42 ^{Ca}	20.77±0.40 ^{BcA}	
Control	11.23±0.40 ^{Aa}	15.10±0.85 ^{Ba}	19.57±0.75 ^{Ca}	22.23±0.40 ^{Cc}	21.83±2.15 ^{Ca}	21.77±0.50 ^{Ca}	

Note: Values in Table 4.11 are mean of 3 replicate (3 representatives) samples / replicate). Mean (n=9) ± 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)

4.7 Browning index

Browning index is important to classify the browning level of the treated sliced bananas. This was an overall view of the physical appearance in terms of consumers' eyes and perception. The browning index can be classified into 4 indices, which index 0, index 1, index 2 and index 3.

Each of the indexes has their own percentage according to the changes that occurs on the slices. The browning indices of each period of time, which are at 30 minutes, 60 minutes and 120 minutes were taken and interpreted in Figure 4.8 , 4.9 and 4.10 below. The selections of the time intervals were due to maximum of the common timeline of consumers starting from purchasing the products from the supermarket until they reach their home and re-store the product in the refrigerator.

Figure 4.8 showed the browning index of each treatment after 30 minutes. The trends of the figures were not very clear even though most of it seemed to be increasing in the index values. However, in each 3-day intervals, citric acid (0.5 M) treatment showed the highest browning index throughout the storage time. Control, had increasing index at the last day of storage. On day 0, all the treatments were scaled at index 0 after 30 minutes left at ambient temperature. On day 3, Control had significantly higher index compared to the other treatments. From the Figure 4.8 and Table 4.12, the combination of N-acetylcysteine (0.05 M) and citric acid (0.5 M) had showed the lowest browning index in each 3-day intervals. On the last day of storage, different index were observed among glutathione (0.1 M), N-acetylcysteine (0.05 M), combination of glutathione (0.1 M) and citric acid (0.5 M), combination of N-acetylcysteine (0.05 M) and citric acid

(0.5 M), and Control. However, statistical analysis shown that there had no significant different among all the 4 treatments.

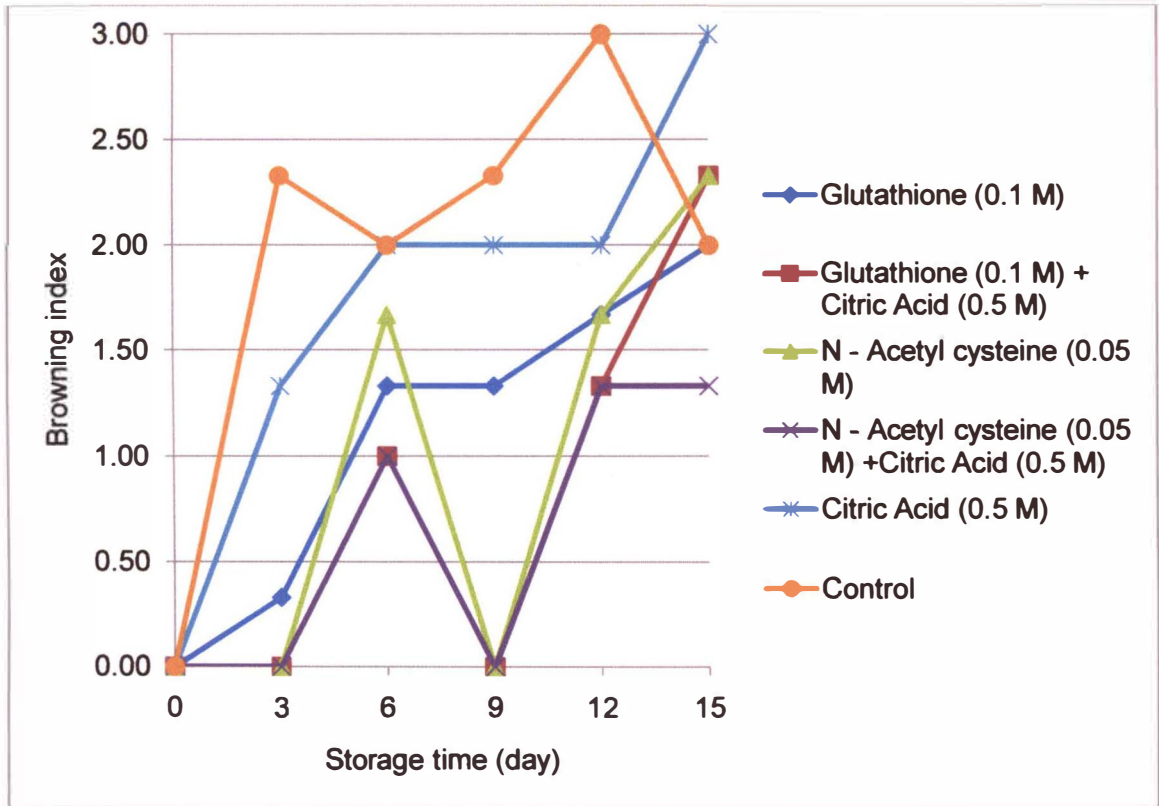


Figure 4.8: The browning index of sliced bananas treated with different anti-browning agents at 30 minutes after left at ambient temperature

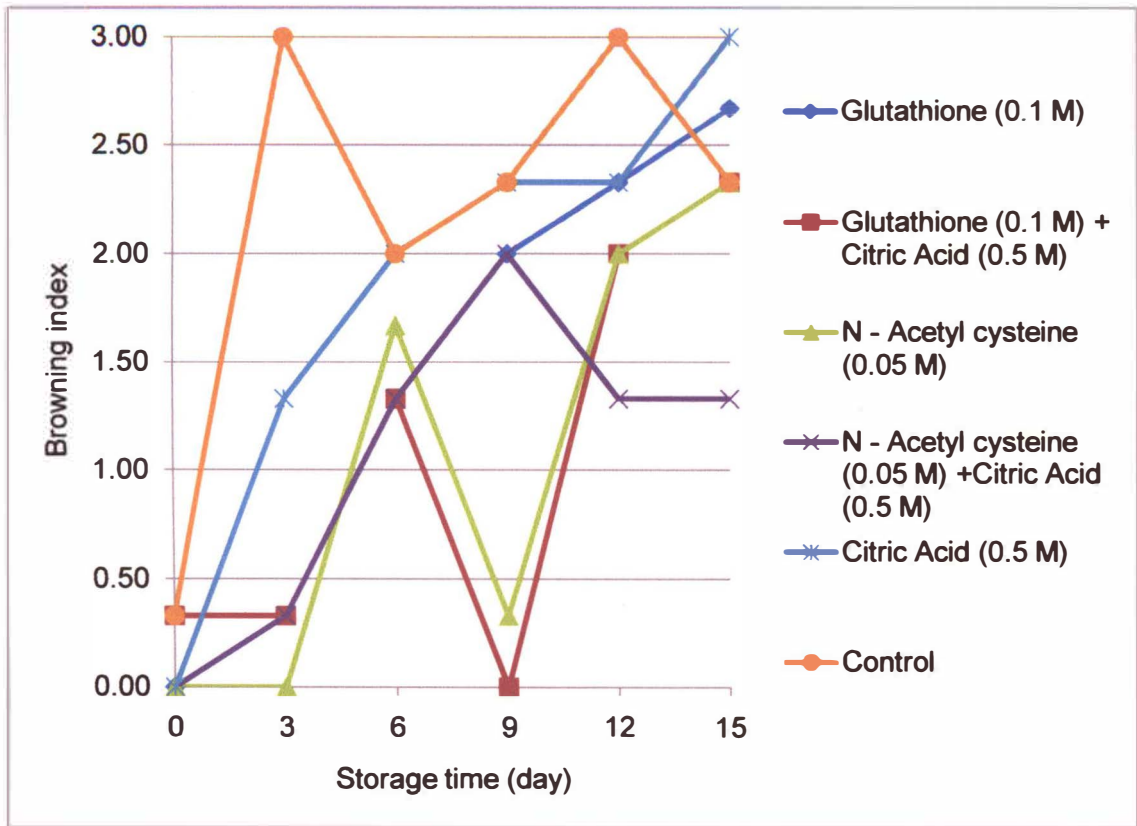


Figure 4.9: The browning index on the slices of different anti-browning agents at 60 minutes after left at ambient temperature.

Figure 4.9 shows the browning index of the treated sliced bananas after 60 minutes left at ambient temperature. The Figure shows that Control scaled at the highest index of browning. This indicating that the Control had undergone browning activity rapidly if compared to the other treatments. However, there was no significantly different of Control to the other treatments on day 0 and day 6. On day 3, Control showed the highest index of browning and this result based to the statistical analysis done (Table 4.13) which showed that Control was significantly higher to the other treatments. On the last week of storage, Control was not significantly different to glutathione (0.1 M),

combination of glutathione (0.1 M) and citric acid (0.5 M), N-acetylcysteine (0.05 M), and combination of N-acetylcysteine (0.05 M) and citric acid (0.5 M). Meaning that Control and the other treatments mentioned did not have any absolute changes.

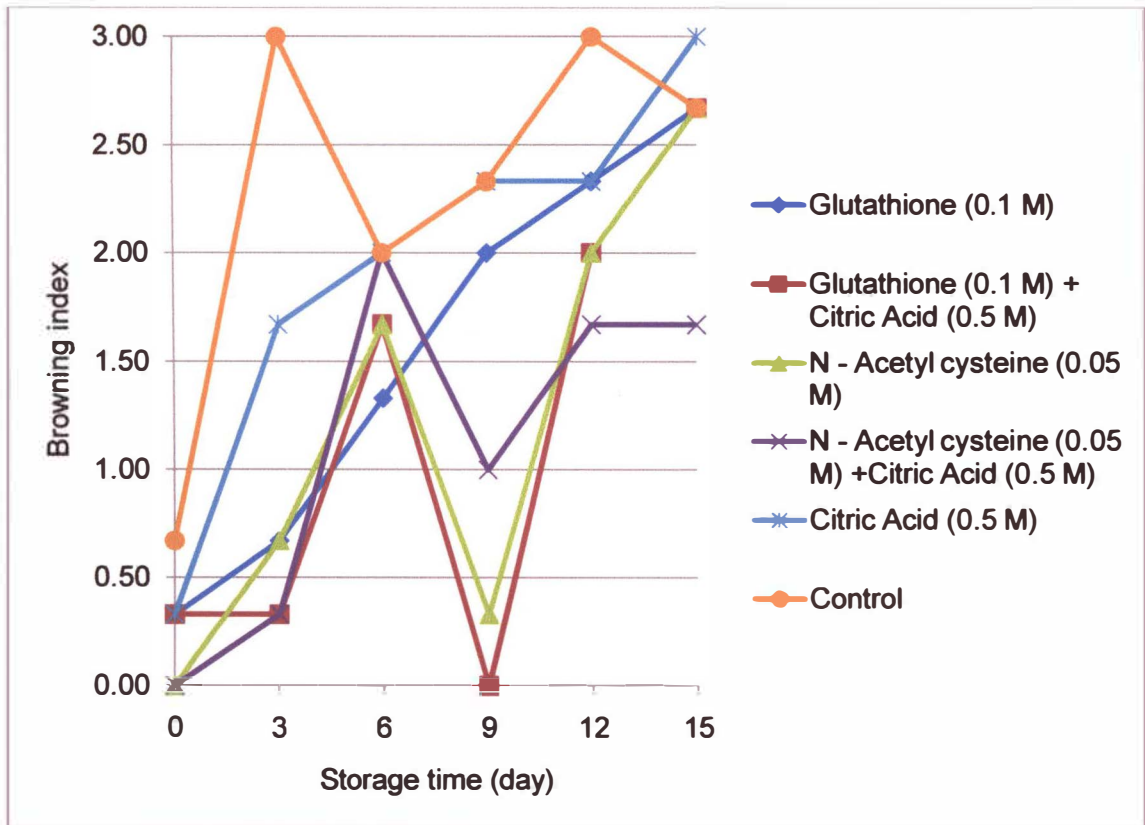


Figure 4.10: The browning index on the slices of different anti-browning agents at 120 minutes after left at ambient temperature.

The Figure above shows the browning index of the treated sliced bananas after 120 minutes left at ambient temperature. Control showed the highest browning index on day 0, day 3, day 6, day 9 and day 12 if compared to the other treatments. By the way, there is no significant different (Table 4.14) of Control to the other treatments on day 0, day 6, and day 15.

Control was significantly higher to the other treatments on day 3, day 9 and day 12. Same thing happened on at the 60 minutes after the samples were left at ambient temperature, the combination of N-acetylcysteine (0.05 M) and citric acid (0.5 M) showed the least changes in the browning index.

Table 4.12: Effect of anti-browning agents on browning index sliced banana at 30 minutes

Treatment	Browning index					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Glutathione (0.1 M)	0.00±0.00 ^{Aa}	0.33±0.58 ^{ABbb}	1.33±0.58 ^{Bca}	1.33±0.58 ^{Bcb}	1.67±0.58 ^{Ca}	2.00±0.00 ^{Cab}
Glutathione (0.1 M) + Citric Acid (0.5 M)	0.00±0.00 ^{Aa}	0.00±0.00 ^{Aa}	1.00±0.00 ^{Ba}	0.00±0.00 ^{Aa}	1.33±0.58 ^{Ba}	2.33±0.58 ^{Cab}
N - Acetyl cysteine (0.05 M)	0.00±0.00 ^{Aa}	0.00±0.00 ^{Aa}	1.67±0.58 ^{Ba}	0.00±0.00 ^{Aa}	1.67±0.58 ^{Ba}	2.33±0.58 ^{Bbb}
N - Acetyl cysteine (0.05 M) +Citric Acid (0.5 M)	0.00±0.00 ^{Aa}	0.00±0.00 ^{Aa}	1.00±1.00 ^{Aa}	0.00±0.00 ^{Aa}	1.33±0.58 ^{Aa}	1.33±0.58 ^{Aa}
Citric Acid (0.5 M)	0.00±0.00 ^{Aa}	1.33±0.58 ^{Bbc}	2.00±0.00 ^{Ca}	2.00±0.00 ^{Cbc}	2.00±0.00 ^{Cb}	3.00±0.00 ^{Lb}
Control	0.00±0.00 ^{Aa}	2.33±0.58 ^{Bc}	2.00±0.00 ^{Ba}	2.67±0.58 ^{Bc}	3.00±0.00 ^{Bb}	2.00±1.00 ^{Bbb}

Note: Values in Table 4.12 are mean of 3 replicate (3 representatives) samples / replicate). Mean (n=9) ± 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)

Table 4.13: Effect of anti-browning agents on browning index sliced banana at 60 minutes

Treatment	Browning Index					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Glutathione (0.1 M)	0.00±0.00 ^{Aa}	0.33±0.58 ^{ABab}	1.33±0.58 ^{BCa}	2.00±0.00 ^{CDb}	2.33±0.58 ^{Cdab}	2.67±0.58 ^{Dab}
Glutathione (0.1 M) + Citric Acid (0.5 M)	0.33±0.58 ^{ABa}	0.33±0.58 ^{ABab}	1.33±0.58 ^{BCa}	0.00±0.00 ^{Aa}	2.00±0.00 ^{Cab}	2.33±0.58 ^{Cab}
N - Acetyl cysteine (0.05 M)	0.00±0.00 ^{Aa}	0.00±0.00 ^{Aa}	1.67±0.58 ^{Ba}	0.33±0.58 ^{Aa}	2.00±0.00 ^{Bab}	2.33±0.58 ^{Bab}
N - Acetyl cysteine (0.05 M) +Citric Acid (0.5 M)	0.00±0.00 ^{Aa}	0.33±0.58 ^{ABab}	1.33±0.58 ^{Bca}	2.00±0.00 ^{Cb}	1.33±0.58 ^{BCa}	1.33±0.58 ^{Bca}
Citric Acid (0.5 M)	0.00±0.00 ^{Aa}	1.33±0.58 ^{Bb}	2.00±0.00 ^{Bca}	2.33±0.58 ^{Bcb}	2.33±0.58 ^{Bcab}	3.00±0.00 ^{Cb}
Control	0.33±0.58 ^{Aa}	3.00±0.00 ^{Bc}	2.00±0.75 ^{Ba}	2.33±0.58 ^{Bb}	3.00±0.00 ^{Bb}	2.33±0.58 ^{Bab}

Note: Values in Table 4.13 are mean of 3 replicate (3 representatives) samples / replicate). Mean (n=9) ± 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)

Table 4.14: Effect of anti-browning agents on browning index sliced banana at 120 minutes

Treatment	Browning index						
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15	
Glutathione (0.1 M)	0.33±0.58 ^{Aa}	0.67±1.16 ^{ABa}	1.33±0.58 ^{ABCa}	2.00±0.00 ^{ABCbc}	2.33±0.58 ^{BCab}	2.67±0.58 ^{Ca}	
Glutathione (0.1 M) + Citric Acid (0.5 M)	0.33±0.58 ^{Aa}	0.33±0.58 ^{Aa}	1.67±0.58 ^{Ba}	0.00±0.00 ^{Aa}	2.00±0.00 ^{Bab}	2.67±0.58 ^{Ba}	
N - Acetyl cysteine (0.05 M)	0.00±0.00 ^{Aa}	0.68±0.58 ^{ABa}	1.67±0.58 ^{BCa}	0.33±0.58 ^{Aa}	2.00±0.00 ^{Cab}	2.67±0.58 ^{Ca}	
N - Acetyl cysteine (0.05 M) +Citric Acid (0.5 M)	0.00±0.00 ^{Aa}	0.33±0.58 ^{ABa}	2.00±0.00 ^{Ca}	1.00±0.00 ^{ABCab}	1.67±0.58 ^{BCa}	1.67±1.16 ^{BCa}	
Citric Acid (0.5 M)	0.33±0.58 ^{Aa}	1.67±1.16 ^{ABcd}	2.00±0.00 ^{ABa}	2.33±0.58 ^{Bc}	2.33±0.58 ^{Bab}	3.00±0.00 ^{Ba}	
Control	0.67±0.58 ^{Aa}	3.00±0.00 ^{bb}	2.00±0.00 ^{Ba}	2.33±0.85 ^{Bc}	3.00±0.00 ^{bb}	2.67±0.58 ^{Ba}	

Note: Values in Table 4.14 are mean of 3 replicate (3 representatives) samples / replicate). Mean (n=9) ± 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)

CHAPTER 5

CONCLUSION

5.1 Conclusion

Throughout this study, we can investigate the effects of different anti-browning agents on the sliced bananas. The chemical analyses that consist of Total Soluble Solid (TSS) and titratable acidity can be well observed. The physical analyses of percentage of weight loss, browning index, texture and total color change on both side of the sliced can also be used to determine the quality of the sliced bananas. This parameters or analyses are very important in determining the consumers' acceptance on the minimally processed products especially sliced bananas. The best method for reducing the occurrence of browning on the sliced bananas was the combination of N-acetylcysteine (0.05 M) and citric acid (0.5 M), which followed by single treatment of N-acetylcysteine (0.05 M). These treatments have advantages in different aspects of the analyses but still these two treatments are effective in reducing the enzymatic browning in minimally processed bananas.

5.2 Recommendations

For recommendation that related to this study, some modifications and analyses should be added in order to investigate the more effects on different application of anti-browning agents. More treatments should be tested for a wide observation of the browning activities in terms of different types of anti-browning agents and different concentrations. Modifications can also be implemented by using different types of bananas and sensory analysis also should be done in order to observed the level of consumers' acceptance of the minimally processed of bananas treated with these chemicals. This is very important in determining the quality and to analyze the market potential of these products.

REFERENCES

- Altunkaya, A. and Gökmen, V. 2007. Effect of various inhibitors on enzymatic browning antioxidant activity and total phenol content of fresh lettuce (*Lactuca sativa*). *Journal of food chemistry* 107: 1173 – 1179.
- Apintanapong, M., Cheachumluang, K., Suansawan, P. and Thongprasert, N. 2007. Effect of antibrowning agents on slices and vacuum – fried slices. *Journal of food agricultural and environment* 5: 151 – 157.
- Arogba, S.S. 1999. Mango (*Mangifera indica*) kernel:Chromatographic analysis of the tannin ,and stability study of the associated polyphenol oxidase activity. *Journal of food composition and analysis* 13:149 – 156.
- Bico, S.L.S., Raposo, M.F.J., Morais, R.M.S.C., and Morais, A.M.M.B. 2008. Combined effects of chemical dip and/or carrageenan coating and /or controlled atmosphere on quality of fresh – cut banana. *Journal of food control* 20:508 – 514.
- Bolin, H.R, and Huxsoll, C.C. 1989. Storage stability of minimally processed fruits. *Journal of food biochemistry* 13: 281 – 292.
- Brun-Mérimée, S., Billaud, C., Louarme, L., and Nicolas, J. 2003. Effect of glutathione and Maillard reaction products prepared from glucose or fructose with glutathione on polyphenoloxidase from apple – II. Kinetic study and mechanism of inhibition. *Journal of food chemistry* 84: 235 – 241.
- Carlo, L. 2002. Improving the nutritional quality of processed fruits and vegetables: the case of tomatoes. Stazione Sperimentale per l'Industria delle Conserve Alimentari, Parma - © Woodhead Publishing Ltd and CRC Press, LLC
- Clean Air Gardening. 2009. *Clean Air Gardens*. [online]. Available from; www. Clean air gardening. com. [Accessed 1 January 2010]
- Chervin, C., Triantaphylides, C., Libert, M.F., Siadous, R. and Boisseau. 1992. *Postharvest Biology Technology* 2: 7 – 17.
- Chuenboonngarm, N., Niran, J., Arunee E., Wallop A., and Surin, P. 2007. Changing in TSS, TA and Sugar Contents and Sucrose Synthase Activity in Ethephon-Treated 'Pattavia' Pineapple Fruit. *Kasetsart Journal of National Science* 41: 205 - 212 (2007)
- Drake, S.R. and Spayd, S.E. 1983. Influence of calcium treatment on 'Golden Delicious' apple quality. *Journal of food science* 48: 403 – 405.
- FAMA, Industri tanaman pisang. Kuala Lumpur: Federal Agricultural Marketing Authority, 2009.

- Garcia, E. and Barret, D.M. 2009. *Preservative treatments for fresh – cut fruits and vegetables*. Department of food science and technology. University of California, Davis, United State of America.
- González-Aguilar, G.A., Ruiz-Cruz, S., Cruz-Valenzuela, R., Rodríguez-Félix, A., and Wang.C.Y. 2003. Physiological and quality changes of fresh – cut pineapple treated with anti-browning agents. *Journal of food science and technology* 37: 369 – 376.
- Tucker, G., and Grierson, D.1987. Fruit ripening. In: D. Davis, Editor, *Biochemistry of Plants* Volume. 12, Academic Press, New York (1987), pp. 265–318.
- Gunes, G., Splittstoesser, D.F. and Lee,C.Y. 1997. Microbial quality of fresh potatoes: effect of minimal processing. *Journal of Food Protection* 60:863-866.
- Hanotel, L., Fleuriet, A., Boisseau, P. 1995. Biochemical changes involved in browning of gamma-irradiated cut witloof chicory. *Postharvest Biology Technology* 5: 199 – 210.
- Harker, F.R., Redgwell, R.J., Hallet, I.C., and Murray, S.H. 1997. Texture of fresh fruit, *Horticulture Review* 20: 121-205.
- Hassan, A. and Pantastico, ER.B. 1990. Banana; Fruit Development, Postharvest Physiology, Handling and Marketing in ASEAN. ASEAN Food Handling Bureau. Pp 33 – 34.
- Heimdal, H., Kuhn, B.F., Poll, L., Larsen, L.M. 1995. Biochemical changes and sensory quality of shredded and MA–packaged iceberg lettuce. *Journal of food science* 60: 1265 – 1268.
- Heldt, H.W. and Heldt, F. 2004. *Plant Biochemistry*. Germany. Elsevier Academic Press. p 130
- Hopfinger, J.A., Poovaiah, B.W. and Patterson, M.E. 1984. Calcium and magnesium interactions in browning of ‘Golden Delicious’ apples with bitter pit. *Science horticulture*. 23: 345 – 351.
- Israeli, V. and Lahav,E. Banana:In Mouseksi,S.P. 1988. Handbook of fruit set and development. Florida:CRC Press,Inc.,1986: 45-79.
- Iyengar, R. and McEvily, A.J. 1992. Antibrowning agent: alternatives do the use of sulfites in foods. *Trends of food science technology*.3: 60 – 64.
- Kader, A.A. 1992. Postharvest biology and technology: an overview. In A.A.Kader, ed., *Postharvest technology of horticulture crops*. University of California, Division of Agriculture and Natural Resources, Publication 3311, pp,15 – 20.
- Kilcast, D. 1999. Sensory techniques to study food texture. In *Food Texture: Measurement and Perception*. Ed. A J Rosenthal, Gaithersburg, MD., Aspen, 30–64.

- King, D.A., and Bolin, H.R. 1989. Physiological and microbiological storage stability of minimally processed fruits and vegetables. *Food Technology*. 43,132
- King Jr, A.D., Magnuson, J.A., Török, T. and Goodman, N. 1991. Microbial flora and storage quality of partially processed lettuce. *Journal of food science* 56: 459 – 461.
- Laws of Malaysia. Act 281. Food Act 1983.Incorporating Latest Amendment-Act A1266/2006.
- Lizada, M.C.C., Uy, W.T, Mendoza, D.B., Novenario, V. 1990. The effect of prolong on patterns of physico-chemical and physiological changes in the ripening bananas.Laguna:PHTRC, 1990. Annual report.
- Mayer, A. and Harel, E. 1992. Phenoloxidases and their significance in fruit and vegetables.In P.F.Fox,ed."Food Enzymology", v.1, Elsvier, London, Pp. 373 – 398.
- McEvily, A.J., Iyengar, R. and Otwell, W.S. 1991. Sulfite alternative prevents shrimp melanosis. *Food Technology*. 9: 80-86.
- Mohd Noor, L. 2009. Proses minimum buah – buahan dan sayur – sayuran. MARDI brochures.
- Nguyen-the, C. and Carlin, F. 1994. The microbiology of minimally processed fresh fruits and vegetables.CRC Crit.Review. *Food Science and Nutrition*.34:371-401.
- Oszmianski, J., and Lee, C.Y. 1990 .Inhibition of polyphenol activity and browning by honey. *Journal of food chemistry* 38: 1892.
- Poovaiah, B.W. 1986. Role of calcium in prolonging storage life of fruits and vegetables. *Food Technology*. 40, 86,.
- Richard – Forget, F.C., Groupy, P.M., and Nicholas, J.J. 1992. Cyateine as an inhibitor of enzymatic browning.2.Kinetic studies. *Journal of food chemistry* 40: 2108 – 2113.
- Richardson, T., and Hyslop, D.B. 1985. *Enzyme:In Food Chemistry*, 2nd ed., O.R, Fennema, ed. New York, Marcel Dekker, pp.371 – 476.
- Robinson, D.S. 1991. *Peroxidase and their significance in fruits and vegetables*. In P.F.Fox , ed."Food Enzymology", Elsvier, London, pp.399 – 426.
- Rosen, J.C. and Kader, A.A. 1989. Postharvest physiology and quality maintenance of sliced pear and strawberry fruits. *Journal of food science* 54:656 – 659.
- Rouet – Mayer, M.A. and Philippon, J. 1986. Inhibition of catechol oxidases from apples by sodium chloride. *Phytochemistry* 25 (12):2717 – 2719.
- Sapers, G.M., and Hicks, K.B., Philips, J.G., Garzarella, L., Pondish, D.L., Matulaitis, R.M., McCormack, T.J., Sondey, S.M., Seib, P.A. and El-Atawy, Y.S. 1989.

Control of enzymatic browning in apple with ascorbic acid derivatives, polyphenol oxidase inhibitors, and complexing agents. *Journal of food science* 54: 997 – 1002, 1012

Son, S.M., Moon, K.D. and Lee, C.Y. 2000. Inhibitory effects of various anti-browning agents on apple slices. *Journal of food chemistry* 73: 23 – 30.

Sirisomboon, P., Tanaka, M., Fujita, S., and Kojima, T. 2000. Relationship between the texture and pectin constituents of Japanese pear. *Journal of Texture Studies* 31 (2000), pp. 679–690.

Tauxe, R. *et al.*, 1997, Microbial hazards and emerging issues associated with produce: a preliminary report to the National Advisory Committee on Microbiological Criteria of Foods. *Journal of Food Protection*. 60:1400–1408.

Vandamme. *History of bananas*. 2009. [online]. Available from; <http://vandamme.historyofbananas.com>. [Accessed 3 March 2010].

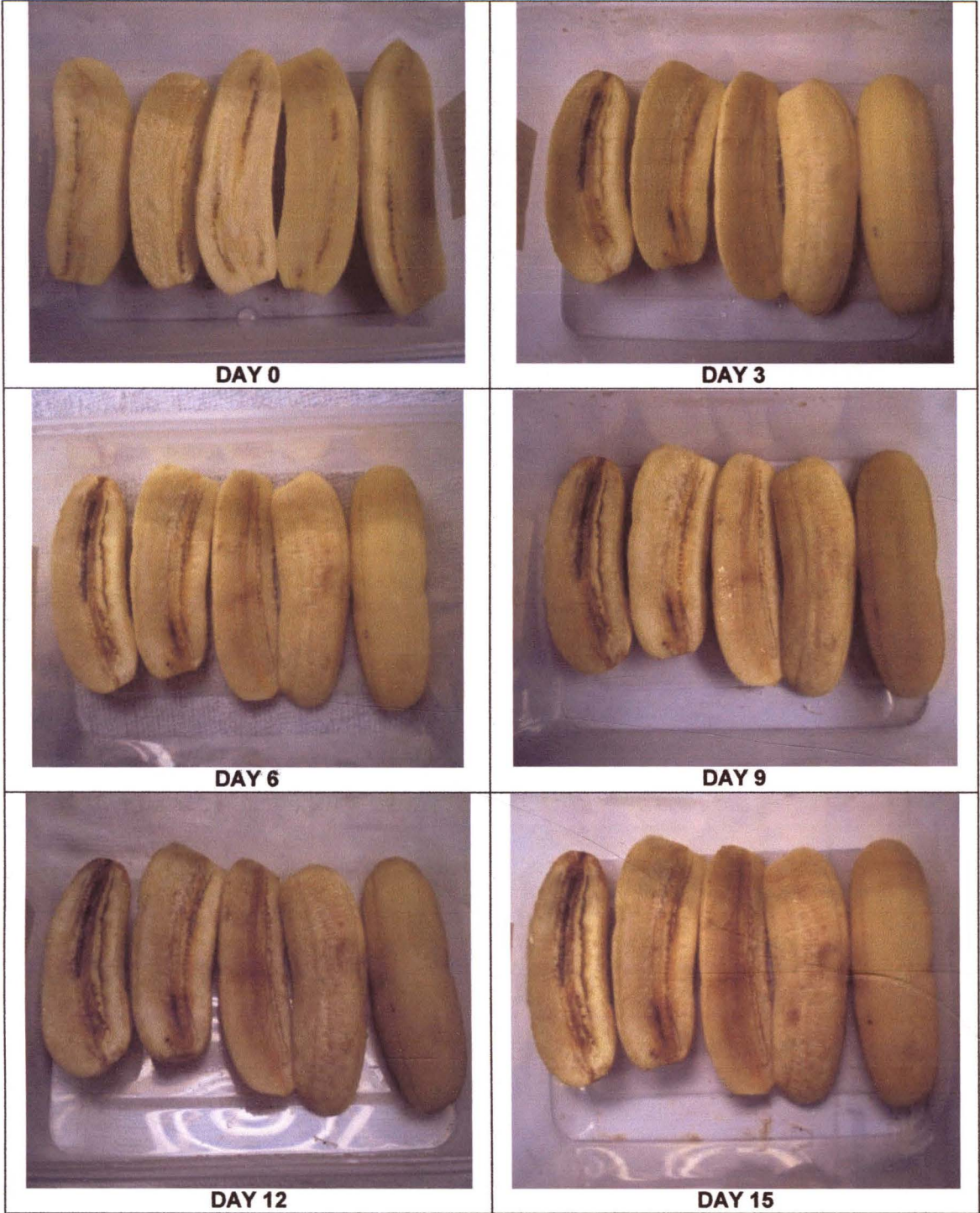
Varaquaux, P., Lecendre, I., and Varaquaux, F. 1990. Changes in firmness of kiwifruit after slicing. *Science Aliments*. 10,127.

Wills, R.H.H, Lee, T.H., Graham, D., McGlasson, W.B. and Hall, E.G. 1981. An introduction to the physiology and handling of fruits and vegetables. New South Wales University Press Limited.pg:30-33.

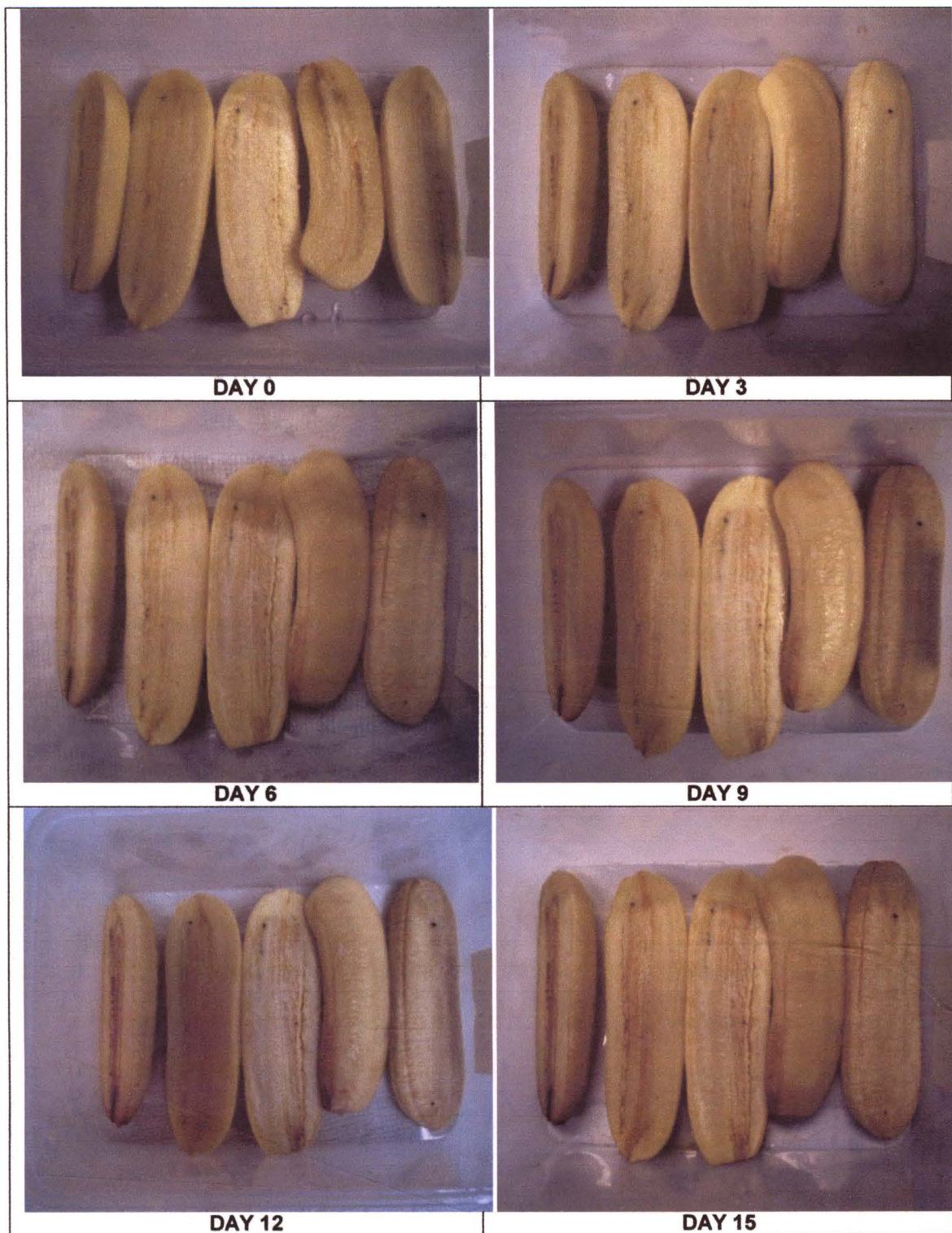
Wills, R., McGlasson, B., Graham, D. and Joyce, D. 1998. Postharvest. An introduction to the physiology and handling of fruit, vegetables and ornamentals. Adelaide, UNSW Press, 4th eds., p.262.

Wong Wee Chong. 2004. Manual 1: A practical approach to implement Good Hygiene and Manufacturing Practices. Unicef Pty Limited.

APPENDIX A: ENZYMATIC BROWNING ON THE SLICED BANANAS TREATED WITH GLUTATHIONE (0.1 M)



APPENDIX B: ENZYMATIC BROWNING ON THE SLICED BANANAS TREATED WITH GLUTATHIONE (0.1M) AND CITRIC ACID (0.5 M)



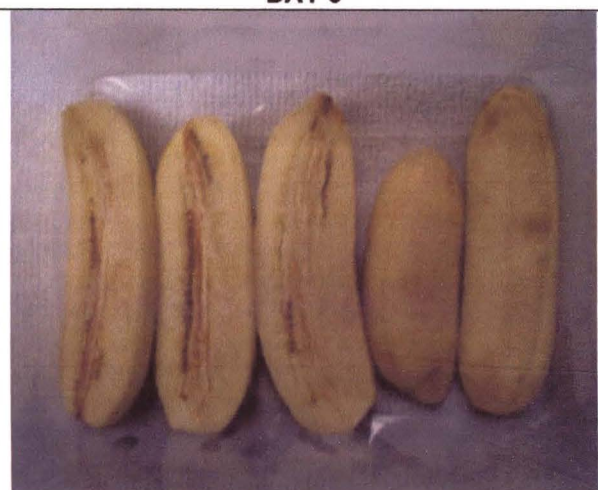
APPENDIX C: ENZYMATIC BROWNING ON THE SLICED BANANAS TREATED WITH N-ACETYLCYSTEINE (0.05 M)



DAY 0



DAY 3



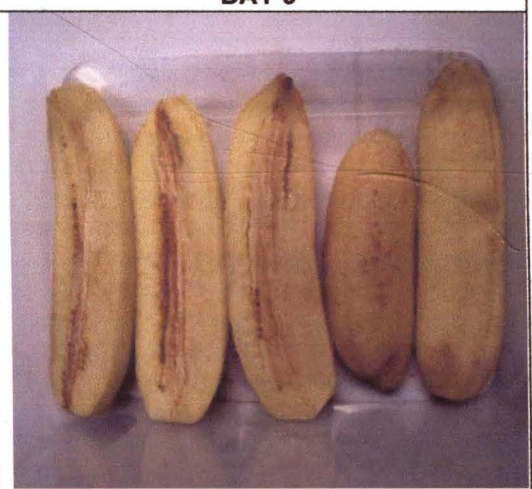
DAY 6



DAY 9

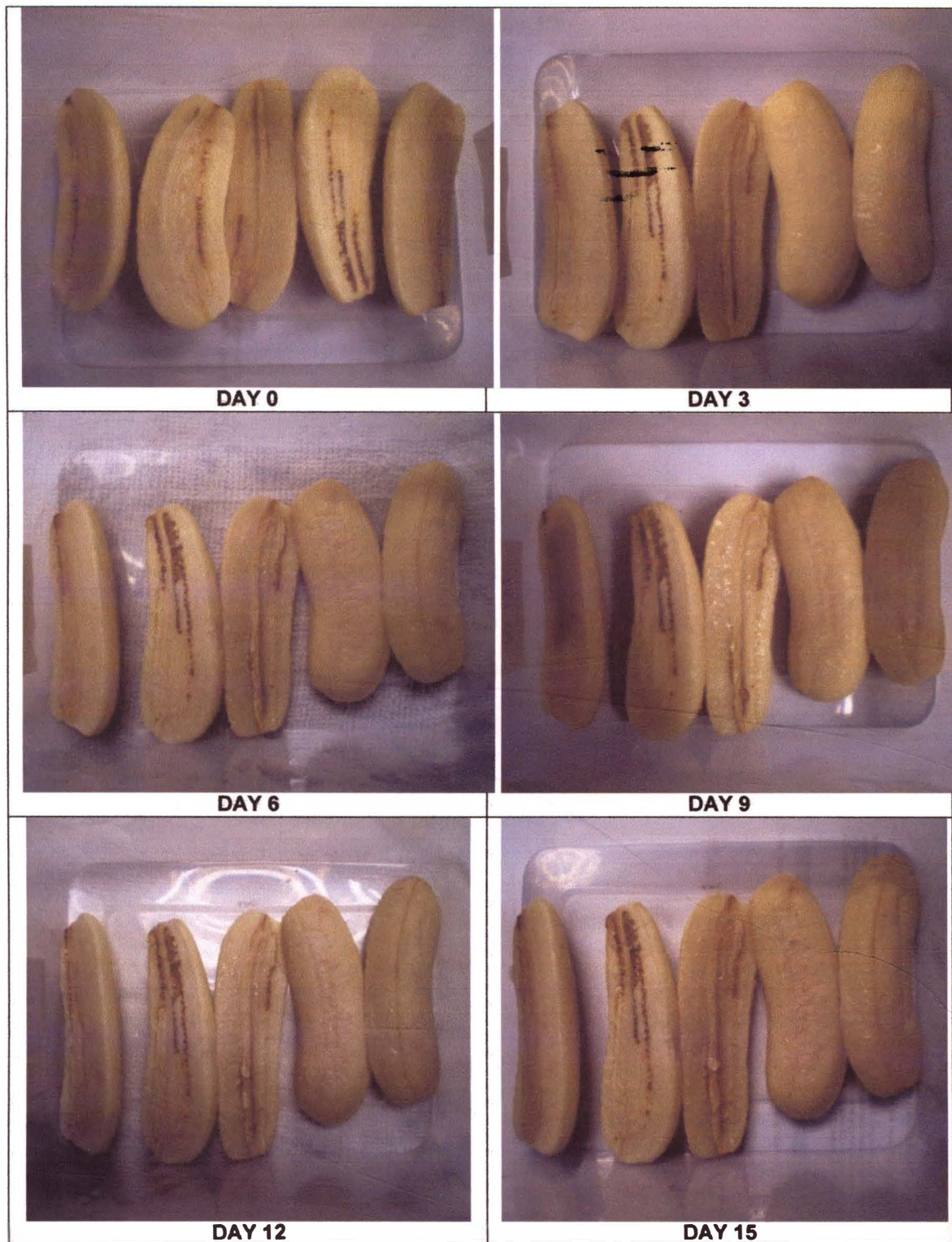


DAY 12

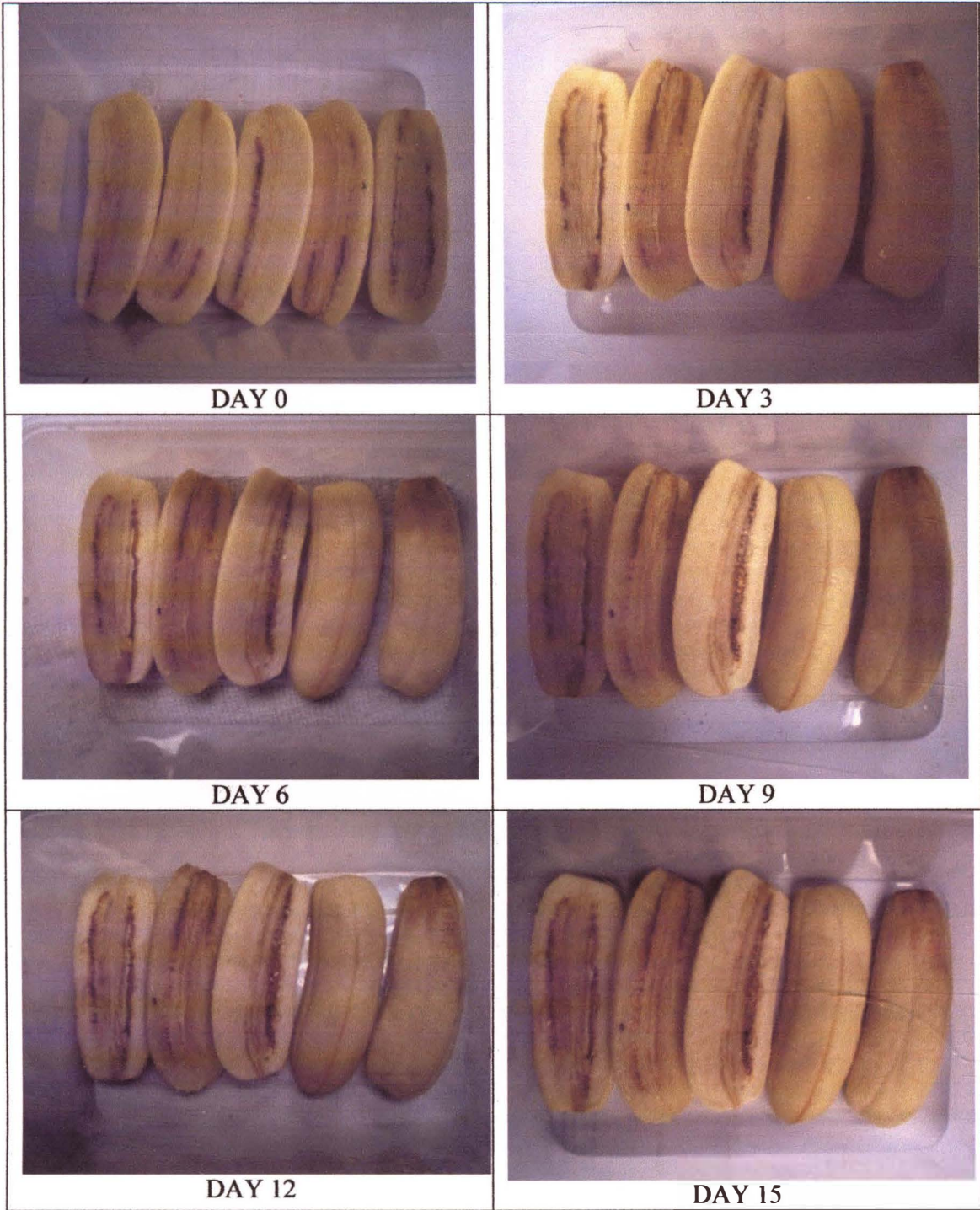


DAY 15

APPENDIX D: ENZYMATIC BROWNING ON THE SLICED BANANAS TREATED WITH N-ACETYLCYSTEINE (0.05 M) AND CITRIC ACID (0.5 M)



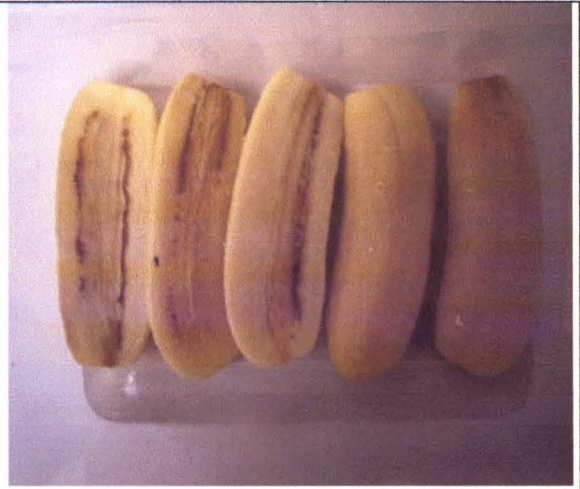
APPENDIX E: ENZYMATIC BROWNING ON THE SLICED BANANAS TREATED WITH CITRIC ACID (0.5 M)



APPENDIX F: ENZYMATIC BROWNING ON THE SLICED BANANAS WITHOUT ANTIBROWNING TREATMENT (CONTROL)



DAY 0



DAY 3



DAY 6



DAY 9



DAY 12



DAY 15

CURRICULUM VITAE (CV)



PERSONAL DIRECTORY

Name : Nurul Syazila bt Abd Rani

Permanent address : No k43 B, Jalan Kampung Batas Lintang, 02700,
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Mobile : 017 – 5626867, 012-4669526

Date of Birth : January 28th 1988

Language (Written) : English (good)
: Malay (good)

Language / (Spoken) : English (good)
: Malay (good)

WORK EXPERIENCE

- Has experienced the working experiences during industrial training at MARDI and has the experiences in agricultural sectors (MEI- end of JUN 2009).

ACADEMIC QUALIFICATION

2010 : PNGK 3.62

2006	: PNGK 3.21 (Matriculation)
2005	: Sekolah Menengah Kebangsaan Agama (Perempuan), Kangar, Perlis 8As, 2Bs and 2Cs (SPM)
2003	: Sekolah Menengah Kebangsaan Agama (Perempuan), Kangar, Perlis 9As (PMR)
2000	: Sekolah Menengah Kebangsaan Simpang Empat, 3As and 2Bs (UPSR)

AWARDS AND HONOURS

- Received the awards of PERMATA as the award for the best students in PMR and SPM.

EXTRACURRICULAR ACTIVITIES

2007 -2008 (TILL NOW)	: Member of Civil Defense Department (JPA3)/sispa : Volunteer of Flood Service in Pekan, Pahang - JPA3 (2007) : Members of Post –Harvest Technology of UMT (2007- till now)
2004 – 2005	: Participate in Perlis State Tourism Quiz : Participate in State (Perlis) Biology Research and Development (R&D) Competition (3 rd place final) : Treasurer of school’s Islamic Club (2005) : Participate in State (Perlis) Consumer Quiz : Participate in State Coral Speaking Competition (1 st place in final)

PERSONAL DATA

I.C Number : 880128-09-5036
Citizen : Malaysian
Age : 22 years old
Sex : Female
Marital Status : Single
Health : Good health status
Race : Malay
Religion : Islam
Height / Weight : 164 cm / 48 kg
Hobbies / Interest : Surfing the Internet , gardening and reading
Personality : Outgoing and well-planned
Pleasant and able to communicate with different types of people.

ACADEMIC REFEREES

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EFFECTS OF SELECTED ANTI-BROWNING TREATMENTS ON THE STORAGE QUALITY OF FRESH-CUT BANANA - NURUL SYAZILA BT ABD RANI