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EFFECTS OF TARTARIC ACID ON BROWNING AND FIRMNESS OF BEAN SPROUTS AND SHREDDED CABBAGES WITH DIFFERENT IMMERSION PERIOD

By

Noraini bt Mohamad Daud

Research Report submitted in partial fulfillment of

the requirements for the degree of

Bachelor of Science Agrotechnology (Post Harvest Technology)

DEPARTMENT OF AGROTECHNOLOGY

FACULTY OF AGROTECHNOLOGY AND FOOD SCIENCE

UNIVERSITI MALAYSIA TERENGGANU

2010

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ENDORSEMENT

The project report **effects of tartaric acid on browning and firmness of bean sprouts and shredded cabbages** by **Noraini bt Mohamad Daud**, Matric No **UK15828** has been reviewed and corrections have been made according to the recommendations by examiners. This report is submitted to the Department of Agrotechnology in partial fulfillment of the requirement of the degree of Bachelor of Science Agrotechnology (Post Harvest Technology), Faculty of Agrotechnology and Food Science. Universiti Malaysia Terengganu.

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(DR CHUAH TSE SENG)
Main supervisor

Date: 29 APRIL 2010

DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged.

Signature : 

Name : NORAINI BT MOHAMAD PAUD

Matric No : UK15828

Date : 29 APRIL 2010

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ABSTRACT

A study to investigate the effectiveness of anti browning agent of tartaric acid in inhibiting enzymatic browning and loss in firmness of bean sprouts and shredded cabbages was conducted under laboratory conditions. Tartaric acid, a member of phenolics acids group which belongs to carboxylic acid group was subjected to bean sprouts and shredded cabbages under ambient temperature (28°C) with different of immersion periods of two, four, six and eight hours and stored for 72 hours. The results of this study have shown that 0.0035% of tartaric acid can inhibit firmness loss in of bean sprouts and shredded cabbages when being immersed for two hours in tartaric acid solutions. Similarly, this combination exhibited significant effect on preventing bean sprouts and shredded cabbage from the occurrence of enzymatic browning.

ABSTRAK

Satu kajian untuk mengetahui ataupun mengenali keberkesanan ejen anti pemerangan asid tartarik dalam menghalang pemerangan berenzim serta juga kehilangan sifat kesegahan taugeh dan hirisan kobis telah dijalankan di makmal. Asid tartarik merupakan kumpulan asid fenolik yang juga kumpulan asid karboksilik , iaitu merujuk kepada taugeh dan hirisan kobis yang di bawah suhu bilik (28C) dengan perbezaan waktu rendaman iaitu dua, empat, enam dan lapan jam selama 72 jam. Hasil daripada kajian ini telah menunjukkan 0.0035% asid tartaric mampu menghalang taugeh dan hirisan kobis daripada kehilangan sifat kesegahannya apabila direndam selama dua jam di dalam larutan asid tartarik. Tambahan pula, kombinasi ini memberikan kesan yang penting dalam menghalang taugeh dan sayur kobis yang di potong halus daripada pemerangan berenzim.

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LIST OF ABBREVIATIONS

°C	Degree celcius
POD	Peroxidase
PPO	Polyphenol oxidase
TA	Tartaric acid
MPV	Minimally processed vegetables
%	Percent
H_2O_2	Hydrogen peroxide
4HR	4-hexylresorcinol
EDTA	Ethylenediamine tetraacetic acid

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

From the quality standpoint, it is desirable to preserve the characteristics of fresh fruits and vegetables at their peak. What the consumer perceives as the most appealing attributes of these products include their fresh-like appearance, taste and flavor, in addition to convenience (Laminkara, 2002). The primary quality attributes of a food product include color, texture, flavor and nutritional value. When assessing plant product quality, consumers take product appearance into consideration as a primary criterion, and color is probably the main factor considered (Kays, 1999). Preservation of chlorophyll in vegetables, red to purple anthocyanins, and yellow, orange and red carotenoids in fruits and vegetables is of vital importance to maintain quality. Color changes in fruits and vegetables may have different origins. For example, decrease green pigmentation in fresh-cut lettuce may result from senescence, heat exposure or acidification (Laminkara, 2002).

Enzymatic browning is one of the most limiting factors on the shelf life of fresh products and also fresh-cut products. In most foods, the browning process has two components which are enzymatic and nonenzyamtic browning. This unfavorable darkening results in a loss of nutritional and market values related to its quality (Friedman, 1996). Enzymatic browning is the discoloration that results from the action of a group of enzymes called polyphenol oxidase (PPOs), which have been reported to occur in all plants and exist in particularly high amounts in mushroom, banana, avocado, apple, pear and peach (Laminkara, 2002). Enzymatic conversion of naturally occurring phenolic compounds results in formation of brown pigments affecting sensorial quality, nutritional value and thus marketability of the food product. In spite of this, the browning reaction is desirable when it enhances the flavor as well the appearance of some food product such as coffee and tea. The texture of vegetable changes with physiological and processing events and therefore it is time-dependent.

1.2 Problem statement

The browning of tissues can adversely affect flavor and nutritional value of the fruits and vegetables. There are many studies done to find the chemicals or substances that are effective in inhibiting the enzymatic browning of vegetables tissues besides being safe for human consumption and thus replacing the use of sulfites (Nor Azian, 2009). Sulfite is a chemical that had been widely used back in 1986 in preventing enzymatic browning. Negative side effects of sulfites to human

health had led to the ban of this chemical. Through many studies, Nicholas et al. (1994) finally reported that several chemical compounds have the ability to inhibit browning in apple and apple products based on the research done on apple slices. Furthermore, the efficiency of 4-hexylresorcinol has been demonstrated in preliminary tests carried out using cut apples and potatoes (McEvily et al., 1991). Those report have sought out a problem regarding the oppress of enzymatic browning. However, the ability that has been mentioned varies among different commodities depending on the concentration of phenolic compound within the fruits and vegetables. There are five major chemical groups said to be effective in inhibiting the enzymatic browning. Two of them are phenolic acids (kojic acid) and carboxylic acid which is tartaric acid. Kojic acid shows the highest potency among phenolic acids tested in preventing apple browning (Son et al., 2001). However, there is a restriction of using this chemical in terms of availability, variable and potency and safety. High intake of kojic acid (>0.5%) in daily diet may lead to cancer (Duriat, 2009). Tartaric acid is the second most effective browning inhibitor among carboxylic acids. It also can lower the possibilities of disease that might occur due to the consumption of vegetables and fruits treated with those chemicals.

1.3 Significance of study

Bean sprouts and shredded cabbages rich in digestible energy, bio-available vitamins, minerals, amino acids, proteins, beneficial enzymes and phytochemicals, as these nutrients are essential for human health (Chavan and Kadam, 1989). However,

it is difficult to maintain the freshness of bean sprout and shredded cabbages because it is very perishable and high in enzymatic changes which can cause browning. Post-harvest handling must be practiced to prevent from contamination, color changes and also enzymatic changes. Nowadays, we can see at the market that sprouts immersed in water to maintain freshness of sprout. This technique has not been supported with any scientific evidence. However, it is believed that the water serves as a medium that can maintain, reduce and lower temperature of sprout thus extending shelf life but cannot prevent from browning to occur. This technique also still not comfortable and not effective because any microorganisms that exist in the water will lead to PPO and POD response. Currently, only whole cabbage is available in market. cabbages should be sold as minimally processed vegetables (MPV) because consumption of MPV is rapidly increased and new products are continually being developed. However, no research has been conducted to find anti browning agent on both sprouts and minimally processed cabbages.

1.4 Objective

This study was conducted to determine suitable concentration and immersion period of an anti-browning agent namely tartaric acid on extending shelf life of mung bean sprouts and shredded cabbages.

CHAPTER 2

LITERATURE REVIEW

2.1 Enzymatic browning

Enzymatic browning is one of the most limiting factors on the shelf life of fresh products and also fresh-cut products. During the preparation stages, produce is submitted to operations where cells broken, causing enzymes to be liberated from tissues and put in contact with their substrates. Enzymatic browning is the discoloration that results from the action of a group of enzymes called polyphenol oxidase (PPOs), which have been reported to occur in all plants and exist in particularly high amounts in mushroom, banana, avocado, apple, pear and peach (Laminkara, 2002). Enzymatic browning must be distinguished from non-enzymatic browning, which results upon heating or storage after processing of foods. Types of non-enzymatic browning include the Maillard reaction, caramelization and ascorbic acid oxidation.

Enzymatic browning is a complex process that can be subdivided in two parts. The first part is mediated by PPO, resulting in the formation of *o*-quinones (slightly

colored), which through nonenzymatic reactions, lead to the formation of complex brown pigments. *o*-Quinones are highly reactive and can rapidly undergo oxidation and polymerization. *o*-Quinones react with other quinine molecules, with other phenolic compounds, with the amino groups of proteins, peptides and amino acid (Whitaker and Lee, 1995). Usually, brown pigments are formed, but in addition, reddish-brown, blue-gary and even black discolorations can be produced on some bruised plant tissues. Color variation in products of enzymatic oxidation is related to the phenolic compounds involved in the reaction (Amiot et al., 1997), and both color intensity and hue of pigments formed vary widely (Nicolas et al., 1993). Consequences of enzymatic browning are not restricted to discoloration, undesirable tastes can also be produced, and loss of nutrient quality may result (Vámos-Vigyázó, 1981). PPO has been considered one of the most damaging enzymes to quality maintenance of fresh produce (Whitaker and Lee, 1995), and prevention of enzymatic browning has always been considered a challenge to food scientist (Ponting, 1960) .

The shelf life of bean sprouts and shredded cabbages are strongly limited by enzymatic browning that leads to a decrease in food quality, since it implies spoilage. Enzyme-catalysed browning reactions involve the oxidation of phenolic compounds by the enzyme polyphenoloxidase (PPO) that act as catalyst in two different reactions which the hydroxylation of monophenols to *o*-diphenols and the oxidation of *o*-diphenols to *o*-quinones. These *o*-quinones are highly reactive compounds that react non-enzymatically to give rise to brown, black or red pigments, called melanins, that are responsible for less attractive appearance and loss in nutritional quality (Tomas-Barberan and Espin, 2001 and Cantos et al., 2002). These reactions result in a deterioration of flavor, color and nutritional quality, and continue after the food is

harvested (Friedman, 1997). The most important factors determining the rate of enzymatic browning in fruit and vegetables are the concentrations of active PPO and phenolic compounds, pH, temperature, and oxygen availability in the tissues (Martinez and Whitaker, 1995). In the last few years, great interest has been shown in fruit or vegetables presented for sale which have been conveniently peeled, cored or sliced in prepacked containers (Reyes-Moreno et al., 2001). Minimal processing operations cause the disruption of cellular compartments, allowing the substrate and enzymes located in the chloroplast to come into contact (Rocha and Morais, 2001). The common way of inhibiting the enzymatic browning of bean sprouts and shredded cabbages is to dip, or immerse, them in anti-browning agents. Among such compounds, ascorbic acid inhibits enzymatic browning very effectively, primarily because of its ability to reduce quinones to phenolic compounds before they undergo further reaction to form pigments (Iyengar and McEvil, 1992). Unfortunately, once the ascorbic acid has been completely oxidised to dehydroascorbic acid, the quinones accumulate and undergo browning. Another anti-browning agent widely used in the food industry is citric acid, which may have a dual inhibitory effect on PPO which it lowers the pH and chelates the copper at the active site of the enzyme. In fact, at pH values below 4, the looser binding of copper at the active enzyme site causes the PPO activity to decrease further, permitting the citric acid to remove the copper (Martinez and Whitaker, 1995).

Since browning is an oxidative reaction, it can be retarded by eliminating oxygen from the cut surface of the vegetables. However, this is not always feasible and browning will occur rapidly when oxygen is reintroduced. In recent years, the application of high oxygen atmospheres for packaging ready to eat vegetables has

been evaluated as an alternative preservation technique. High oxygen partial pressures have been found to be particularly effective in inhibiting enzymatic discoloration, preventing anaerobic fermentation reactions and inhibiting microbial growth (Wszelaki and Mitcham, 2000 and Jacxsens et al., 2001). It has been hypothesised that high oxygen levels may cause substrate inhibition of the enzyme PPO or, alternatively, that high levels of subsequently formed colourless quinines could lead to PPO feedback inhibition (Kader and Ben-Yehousha, 2000).

Furthermore, in nature, both enzymes, PPO and POD, acts as bruising response and can exhibit antibacterial and antifungal properties. Bruising results in objectionable brown discoloration when cells have been disrupted by mechanical damage. Bruising is particularly prevalent in potato tubers, which undergo numerous mechanical assaults during harvesting and handling according to Hyde et al.(2003). The resultant product, melanin is brown to black in color and considered objectable to consumer. It is believed that although POD can contribute to enzymatic browning, its role remains questionable (Nicholas et al., 1993) and limited by the existence of hydrogen peroxide (H_2O_2) (Amiot et al., 1997). It is very difficult to observe the significant role of POD activity in enzymatic browning if one of its substrate, H_2O_2 is low in plant cells. Plant cells will regulate H_2O_2 level very tight due to its implications of oxidative injury (Mittler, 2002). So, the changes in POD may be brought about by wounding, physiological strees and infections. However, POD could speed up the browning reactions whenever there is ongoing PPO mediated browning reactions at the same time (Richard-Forget and Gauillard, 1997).

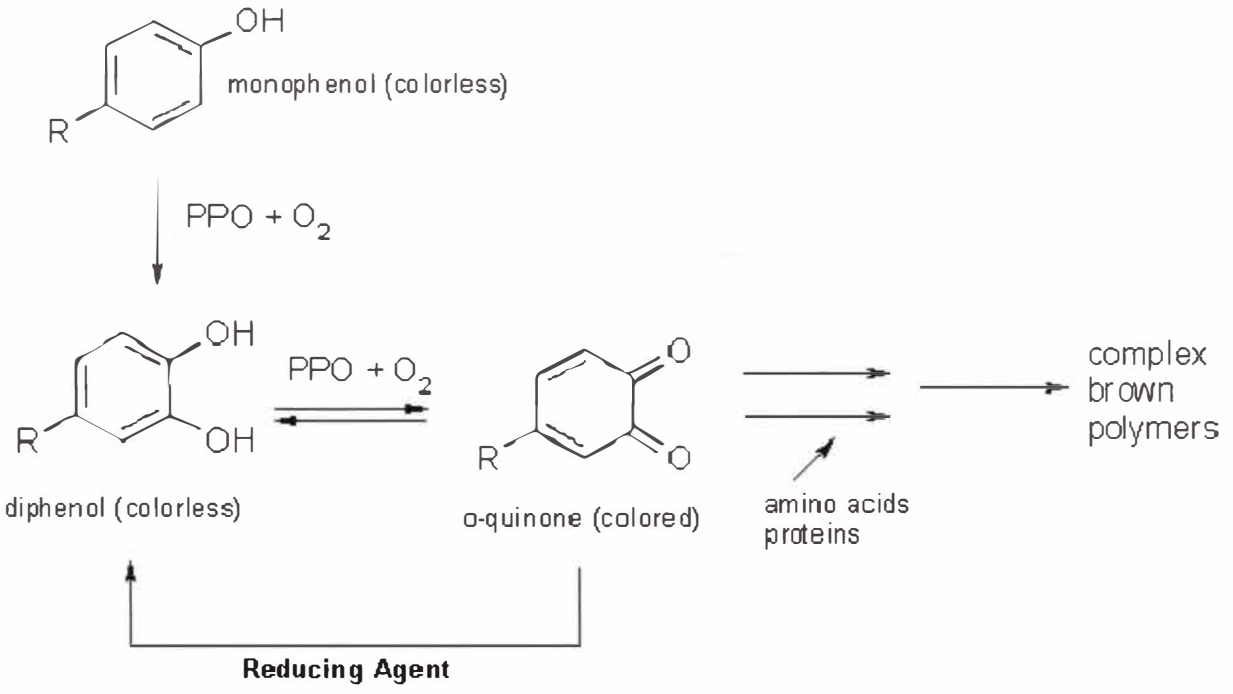

Figure 2.0: Action of polyphenol oxidase (PPOs)

2.2 Textural changes

Texture is a quality attribute that is critical in determining the acceptability of fruits and vegetables. It is convenient to define quality as the composite of intrinsic characteristics that differentiate units of the commodity, individual pieces of the product and to think of acceptability as people's perceptions of and reactions to those characteristics. Although some definitions of texture restrict its use to only sensory

attributes or to sensory attributes and the mechanical properties directly related to them, the term texture is sometimes extended to include some mechanical properties of commercial interest that may not be of direct interest to consumers, such as resistance to mechanical damage. Textural attributes of fruits and vegetables are related to the structural, physiological, and biochemical characteristics of the living cells; their changes over time; and their alteration by processes such as cooking or freezing. The continuous physiological changes in living cells plus the inherent variability among individual units of the commodity make the assessment of fruit or vegetable texture difficult. Because of their continuous change, textural measurements are often relevant only at the time of evaluation; that is, they usually cannot be used to predict condition much later in the storage period or marketing chain. Texture and appearance are two important aspects and characters determining the acceptability of vegetables. Textural changes also the attribute that always being focused by consumer on vegetables. According to Bourne (1982), the definition of textural properties of food is group of characteristics that arise from the structural elements of the food, sensed by the feeling of touch, related to deformation, disintegration and flow of foods under force. The structural changes can be measured by functions of mass, time and distance.

2.3 Bean sprout

Bean sprouts are very rich in nutrients. It is rich in digestible energy, bio-available vitamins, minerals, amino acids, proteins, beneficial enzymes and phytochemicals, as these nutrients are essential for human health (Chavan and Kadam, 1989). Chavan (1989) also concluded that, the desirable nutritional changes that occur during sprouting are mainly due to the breakdown of complex compounds into a more simple form, transformation into essential constituents and breakdown of nutritionally undesirable constituents. Bean sprouts are a tremendous source of plant digestive (Shipard, 2005). The protein content of bean sprouts increased from the time of germination. The absorption of nitrates facilitates the metabolism of nitrogenous compounds from carbohydrate reserves, thus increasing crude protein levels (Morgan et al., 1992). However, bean sprouts turn inedible due to rapid enzymatic browning if the water source and the materials used for germination or storage are contaminated (Nor Azian, 2009). Rough handling and browning on bean sprouts lead to loss of nutrition and quality of bean sprouts.

2.3.1 *Vigna radiate*

In this study, the bean sprout used are mung bean also known as green bean, mung, moong, moog dal (in Bengali), mash bean, munggo or monggo, green gram, golden gram and green soy. It is the seed of *Vigna radiata* which is native to Bangladesh, India, and Pakistan (Figure 2.1). Mung bean sprouts are germinated by leaving them in the water for four hours of daytime light and spending the rest of the day in the dark. Mung bean sprouts can be grown under artificial light for four

hours over the period of a week. Fluorescent bulbs or incandescent light bulbs would be the best to use for mung bean sprouts.

Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Fabales
Family	Fabaceae
Genus	Vigna
Species	Vigna radiate

Table 2.1: Scientific Classification of Bean Sprouts

Figure 2.1: *Vigna radiate*

2.4 Cabbage

Cabbage is a member of brassicaceae family, is an economically and nutritionally important crop being grown in more than ninety countries and consumed widely around the globe (Chiang et al., 1993). Minerals are integral part of human and plant nutrition to support the various biological processes during different stages of growth and developments. Billions of people especially in developing countries suffer from micronutrient malnutrition "Hidden Hunger" caused by insufficient intake of micronutrients such as vitamin-A, zinc and iron (Harvest Plus, 2007). It is more conspicuous in economically poor and developing countries like India particularly after the introduction of green revolution cropping systems which replaced several less popular but nutritionally rich traditional and local crops, and land races. The consequences of which are not only affecting human health and well being adversely, but also stagnating national development by reducing the productivity of an individual and that of a country (Welch and Graham, 1999). Going by a recent estimate, more than two billion people worldwide suffer from anaemia caused by iron deficiency and more than three billion populations suffer from zinc deficiency (Cakmak, 2007). Effects on the appearance and color of whole apples and peaches have been reported by Sy et al. (2005b). More interestingly, these authors also reported darkening immediately after treating minimally processed (MP) cabbage and MP lettuce, which were the MP vegetables used in the present study.

2.4.1 *Brassica oleracea Linne*

Brassica oleracea (Figure 2.2) is a native of the Mediterranean region and southwestern Europe, extending northward to southern England (Vaughan and Geissler, 1997a). It is easy to grow in cold weather, requires moist soil and can tolerate maritime exposure. Horticultural selection within the species has led to the development of a number of cultivars and, although essentially temperate, *B. oleracea* forms are today grown for food everywhere that plants can grow (Vaughan and Geissler, 1997a). The phenolic composition of tronchuda cabbage leaves has already been reported that the external leaves were characterized by the presence of complex flavonol glycosides (Ferreres et al., 2005), while the internal ones exhibited both flavonol glycosides and hydroxycinnamic acid derivatives (Ferreres et al., 2006). The organic acids profile and the antioxidant capacity of external and internal leaves were also previously described (Ferreres et al., 2006 and Vrchovska et al., 2006), with the external ones exhibiting higher antioxidant potential. However, nothing has been reported about tronchuda cabbage seeds. In fact, several studies with other *Brassica* species have been reported the existence of phenolics in the seeds, namely phenolic acids and their derivatives (Baumert et al., 2005, Bouchereau et al., 1991, Li and El Rassi, 2002 and Naczk et al., 1998), flavonoid glycosides (Baumert et al., 2005) and tannins (Naczk et al., 1998).

Table 2.2: Scientific Classification of Cabbage

Kingdom	Plantae
(unranked):	Angiosperm
(unranked):	Eudicots
(unranked):	Rosids
Order:	Brassicales
Family:	Brassicaceae
Genus:	*Brassica*
Species	B. oleracea

Figure 2.2: *Brassica oleracea Linne*

2.5 Minimally processed vegetables (MPV)

The term minimally processed identifies fresh vegetables that have been cut into small serving-size portion and are ready to eat like carrot and lettuce, or to cook like broccoli and sweetcorn (Saltveit, 1997). Consumption of fresh cut vegetables is rapidly increasing and new products are continually being developed. Minimally processed refrigerated fruits and vegetables have become a very important area of potential economic growth in the fresh-cut produce industry (Buta et al., 1999). The economic potential is shown by the solid growth of the industry in the recent past as illustrated by increasing consumption and increasing space devoted to fresh-cut vegetable products in supermarkets and on restaurant menus in most parts of the world (Kaufman et al., 2000). The popularity of fresh-cut vegetables is mainly because today's consumer perceives such products as being fresh, healthy, convenient, tasty, and easy to use in addition to retained nutritional qualities (Wiley, 1994 and Garret et al., 2003). The preparation of fresh-cut vegetables entails physical wounding of the tissues for examples carrots are peeled and cut and lettuce and cabbage are shredded. These unavoidable physical injuries cause both an immediate and subsequent physical and physiological response in the tissue. The immediate physical effects of fresh-cut processing are to cause mechanical shocks to the tissue, to remove the protective epidermal layer, to accumulate surface moisture and to expose tissue to contaminants. Despite the growth of fresh-cut- vegetable produce market (Kaufman et al., 2000), control of microbial spoilage and protection of consumers against microbiological hazard is still a major challenge to the industry (Parish et al., 2003). Such ready-to-use vegetables retain much of their indigenous microflora after minimal processing and pathogens may form part of this microflora, therefore

posing a potential safety problem (Wiley, 1994, Ahevenainen, 1996 and Francis et al., 1999). Since minimally processed vegetables belong to the low-acid foods (pH 5.8–6.0), the characteristic high humidity and the large number of cut surfaces can provide ideal conditions for the growth of microorganisms consequently leading to shelf life reduction (Willocx et al., 1993). Disinfection/ or decontamination is inevitably a critical step in ensuring the safety and shelf life of ready-to-eat vegetables. However, experiments have already shown that feasible decontamination techniques available cannot guarantee the microbiological quality of minimally processed vegetables without compromising their sensorial quality (Beuchat and Ryu, 1997, Beuchat, 1998 and Seymour, 1999). Shredding and slicing or cutting processes are important sources of contamination of minimally processed produce. Shredding and slicing were found to increase counts of mesophilic bacteria from 10^3–10^4 to 10^5–10^6 CFU g^{-1} for a range of vegetables (Garg, et al., 1990). During processing, the mechanical damage caused to cells limits the shelf life of minimally processed fruits and vegetables (King & Bolin, 1989) and provides more entrance points for food borne pathogens. Shredding vegetables changes the surface morphology of the product and, in doing so, changes the surfaces available for bacterial colonization. So, it is better to immerse fresh-cut vegetables such as shredded cabbages in the solution which have low pH because in this condition bacterial growth will be inhibited or reduced. These situations occur due to bacteria and microorganism cannot grow in high acidity environment.

2.6 Anti-browning agent

Nowadays, there are many research have been done on anti-browning agents and effects of them on fruits and vegetables. Through many research done by the researches, several chemical preservatives can be used to control enzymatic browning, loss in firmness and decay (Brecht, 1995). Enzymatic browning is the discoloration that results from the action of a group of enzymes called polyphenol oxidase (PPOs), which have been reported to occur in all plants and exist in particularly high amounts in mushroom, banana, avocado, apple, pear and peach (Laminkara, 2002). The examples of researches have been done are citric acid on pear (Rosen and Kader, 19890, ascorbic acid on apple juice (Sapers et al., 1989), 4-hexylresorcinol on cut apples and potatoes (McEvily et al., 1991), tartaric acid and kojic acid on bean sprouts (Nor Azian, 2009) etc. among these browning inhibitors, ascorbic acid based formulations, cysteine and 4-hexylresorcinol (4HR), have been used commercially with a limited success. The ascorbic acid based formulations require improvement to control color after the reducing activity has been depleted. Cysteine and 4-hexylresorcinol (4HR) are too expensive for commercial us. Additionally, cysteine may produce a sulfury odor at high concentration levels (Mathew and Parpia, 1971). 4HR is not approved by the Food and Drugs administration (FDA) for fresh fruits and vegetables, except for controlling the discoloration of unpeeled shrimp.

Antioxidants are compounds that inhibit or prevent the oxidation reactions caused by free radicals, with or without oxidation enzymes that cause discoloration or browning of certain fruit and vegetable tissues and rancidity of fats (Sapers, 1993; Sherwin, 1990). This can affect the color or flavor of mushrooms and fruit and

vegetable products. The phenolic structure of certain compounds suppresses free radical formation, which delays the auto-oxidative process in fat or oil by acting as a proton donor (Sherwin, 1990). Approved phenolic antioxidants include butylated hydroxyanisole (BHA) are effective. Natural antioxidants also effective, such as tocopherols and lecithin. This antioxidants is approved as a direct food additive and propyl gallate as an indirect food additive and component of coatings. Some agents such as cinnamic acid and benzoic acids (both GRAS-generally recognized as safe) are effective browning inhibitors in combnation with ascorbic acid, since, like sulfites, they inhibit polyphenol oxidase (PPO) activity (Sapers et al., 1989). This enzyme is responsible for the browning that occurs when monophenolic compounds of plants are hydroxylated to *o*-diphenols and subsequently to *o*-quinones in the presence of O_2. The PPO enzyme requires copper; thus complexing and chelating agents such as ethylenediamine tetraacetic acid (EDTA) and citric acid can inhibit enzymatic browning (Sapers, 1993).

Ascorbic acid and its derivatives are effective inhibitors of enzymatic browning for cut apple (Sapers et al, 1991). Ascorbyl palmitate, cinnamic acid, benzoic acid and β-cyclo-dextrin were reported to be effective browning inhibitors in juice (Sapers et al. 1989). Ascorbic acid, erythorbic acid and ascorbyl palmitate are GRAS while the other ascorbic acid derivatives are not yet approved. Citric aid and EDTA have been incorporated into coatings as browning inhibitors for cut apples, potato and mushrooms (Baldwin et al., 1996; Nisperos et al., 1991.

2.6.1 Tartaric Acid

Tartaric acid is one of the most concentrated naturally occurring organic acids in grapes and wine and it is as a by-product of wine production that tartaric acid is prepared on an industrial scale. Tartaric acid is relatively uncommon in other fruits, however, it is found in small amounts in pears and mandarins. Tartaric acid is also used in the production of jams, sweets, jelly, tinned fruit and vegetables, coca powder and frozen dairy produce; mainly as an acidity adjuster but also in the form of an emulsifier. In regard to acid adjustment, tartaric acid is one of the strongest naturally occurring acids in fruit and is the strongest acid in grapes and wine (pK_{a1} = 2.90) (Azab et al., 1997 and Ough and Amerine, 1988). It is well known in the wine industry that tartaric acid is relatively microbiologically stable compared to the other naturally occurring organic acids, such as malic and citric acids.

Most of carboxylic acids have been shown inhibitory effects on enzymatic browning due to their metal-chelating characteristics of lowering pH (Furia, 1964). Tartaric acid in large doses is an unsafe agent, causing gastro-intestinal inflammation and death. The symptoms in man from 1 ounce largely diluted, were intense, burning pain in the stomach, persistent vomiting and death in nine days, the effects being those of a corrosive poison. It is safe for human consumption in 0.05% concentration. 12 g intake may cause fatality death after 12 hours of ingestion. Tartaric acid is refrigerant, antiseptic and antiscorbutic. It is used as a drink in febrile or inflammatory diseases, forming a cooling, refreshing and agreeable acidulous draught. It is less costly than citric acid and may be used instead of this acid to form artificial lemonade. Tartaric

acid is belonging to the best inhibitor group among all the members of carboxylic acids. Apple slices only showed a slight change in color after it was dipped in 0.05% concentration of tartaric acid (Son et al., 2001). The latest study has showed that, 0.0035% of tartaric acid solution can inhibit loss of crunchiness of bean sprouts when immersed in the solution (Nor Azian, 2009).

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

3.1.1 Plant material

The bean sprouts and cabbages were purchased from Mydin Mall, Kuala Terengganu.

3.1.2 Anti-browning agent

Anti-browning agent used was tartaric acid. Tartaric acid is in solid form and 100% pure. It was purchased from Hamburg Chemicals, Germany. The chemical was kept in PVC bottle in ambient temperature and refrigerated at 4°C after being diluted.

3.2 Methods

3.2.1 Bean sprouts preparation

Bean sprouts which were uniform in size and originated from the same source of seeds were used. After bean sprouts were selected, the bean sprouts were washed by using distilled water to remove all the dirt on the surface of bean sprouts. Then, all the bean sprouts were dried by using tissue papers to remove excess water.

3.2.2 Shredded cabbages preparation

Damaged portions of cabbages were removed. After that, cabbages were shredded into the uniform size, washed by using distilled water to remove all dirt and debris on the surface of shredded cabbages. After that, all shredded cabbages were dried by using tissue papers to remove excess water.

3.2.3 Anti-browning Agent treatment

The diluted tartaric acid solutions were placed in empty containers. The washed and dried bean sprouts and shredded cabbages were placed containers containing the solutions of tartaric acid at 0.0035 or 0.0018%, respectively and immersed in the tartaric acid solutions for two, four, six or eight hours in ambient temperature (28°C). After two, four, six or eight hours, bean sprouts and shredded cabbages were removed from the solutions and rinsed with distilled water to eliminate the chemical residues. After that, bean sprouts and shredded cabbages were immersed

in distilled water for 24, 48 and 72 hours respectively. For each treatment, there was three replications. In this experiment, distilled water used as a control.

3.3 Physical analysis

3.3.1 Firmness

The firmness of bean sprouts and shredded cabbages were measured using Texture Analyzer (Stable Micro System) using blade with knife as the probe. The results was expressed as a mean value of compression force in Gram (g) needed to cut the bean sprouts and shredded cabbages horizontally from three replications of each treatment.

3.3.2 Lightness

Bean sprouts and shredded cabbages flesh color were measured using Minolta Chroma Meter Model CR-300 (Minolta. Co. Ltd.,Japan) after 24,48 and 72 hours of storage. The degree of browning was expressed as L value. Three bean sprouts and shredded cabbages were taken from every replicate for the assessment.

3.4 Statistical analysis

In this study, each treatment had three replicates and each replicate had ten sprouts. Statistical analysis was carried out using one way ANOVA, followed by Tukey Test to determine significant difference among all the treatments at the 5% of significant level ($P < 0.05$).

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Firmness of bean sprouts

Figure 4.1 displays firmness changes of bean sprouts immersed at 0.0035% or 0.0018% of tartaric acid solution for two, four, six and eight hours and stored at ambient temperature for three days. All treated bean sprouts showed a decrease in crunchiness during storage. There was significant difference in firmness on bean sprouts immersed at 0.0035 and 0.0018% tartaric acid solution compared to control bean spouts. On day two, bean sprouts immersed at 0.0035 and 0.0018% tartaric acid for two hours had significantly firmer texture compared to control (Appendix A). However, on day three with four and six hours of immersion periods, it is observed that control bean sprouts had higher firmness compared to treated bean sprouts. While, for bean sprouts immersed for eight hours, it is shown that control bean sprouts gave higher firmness compared to treated bean sprouts even on day zero. Hence, the results of this study imply that although bean sprouts treated with 0.0035 or 0.0018% of tartaric acid solution can slow down the reduction of firmness. The bean sprouts

should not be immersed in the solution for a period longer than two hours. This will cause an increase rate of firmness reduction.

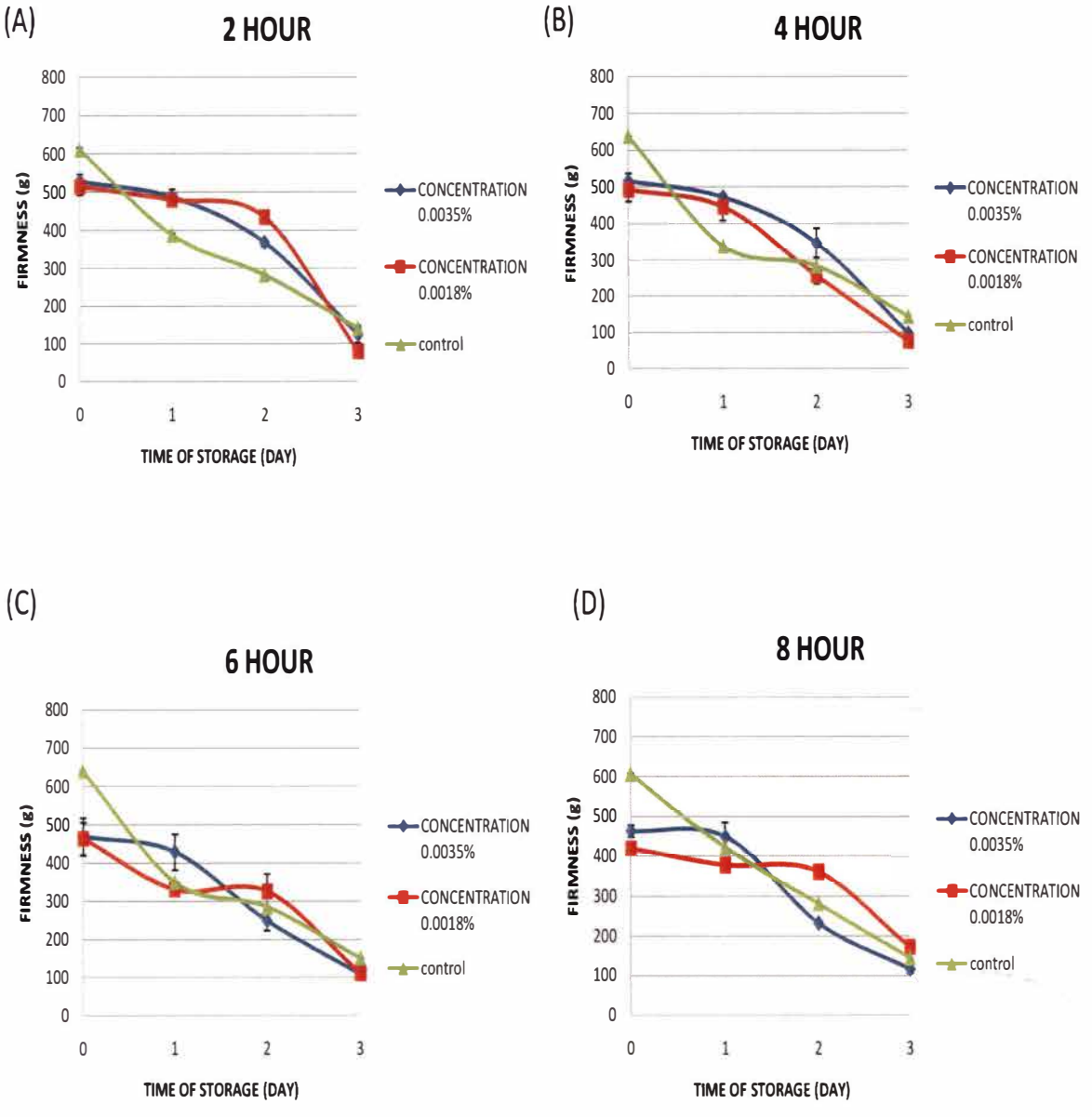

Figure 4.1: Firmness changes of bean sprouts after immersed in tartaric acid solution at a concentration of 0.0018 or 0.0035% for 2(A), 4(B), 6(C) and 8(D) hours and stored at ambient temperature of 28°C for three days.

4.2 Lightness of bean sprouts

Figure 4.2 shows lightness changes of bean sprouts immersed at 0.0035 or 0.0018% of tartaric acid solution for two, four, six and eight hours and stored at ambient temperature for three days. All treatments showed a decrease in lightness during storage. There were significant differences in lightness of bean sprouts immersed at different time lengths of tartaric acid at 0.0035 and 0.0018% compared with control bean spouts. For two hours of immersion period, bean sprouts immersed in 0.0035% tartaric acid had significantly lighter appearance compared to those immersed in 0.0018% tartaric acid and untreated bean sprouts (Appendix B). However, on day three, bean sprouts immersed in 0.0018% tartaric acid and control had higher lightness compared to those treated with 0.0035% tartaric acid. While, for six hours of immersion period in tartaric acid solution, it is found that bean sprouts treated with 0.0035% tartaric acid exhibited higher lightness than that of untreated bean sprouts on day two. These results indicate that both 0.0035 and 0.0018% of tartaric acid solutions can be employed to reduce the browning of bean sprouts.

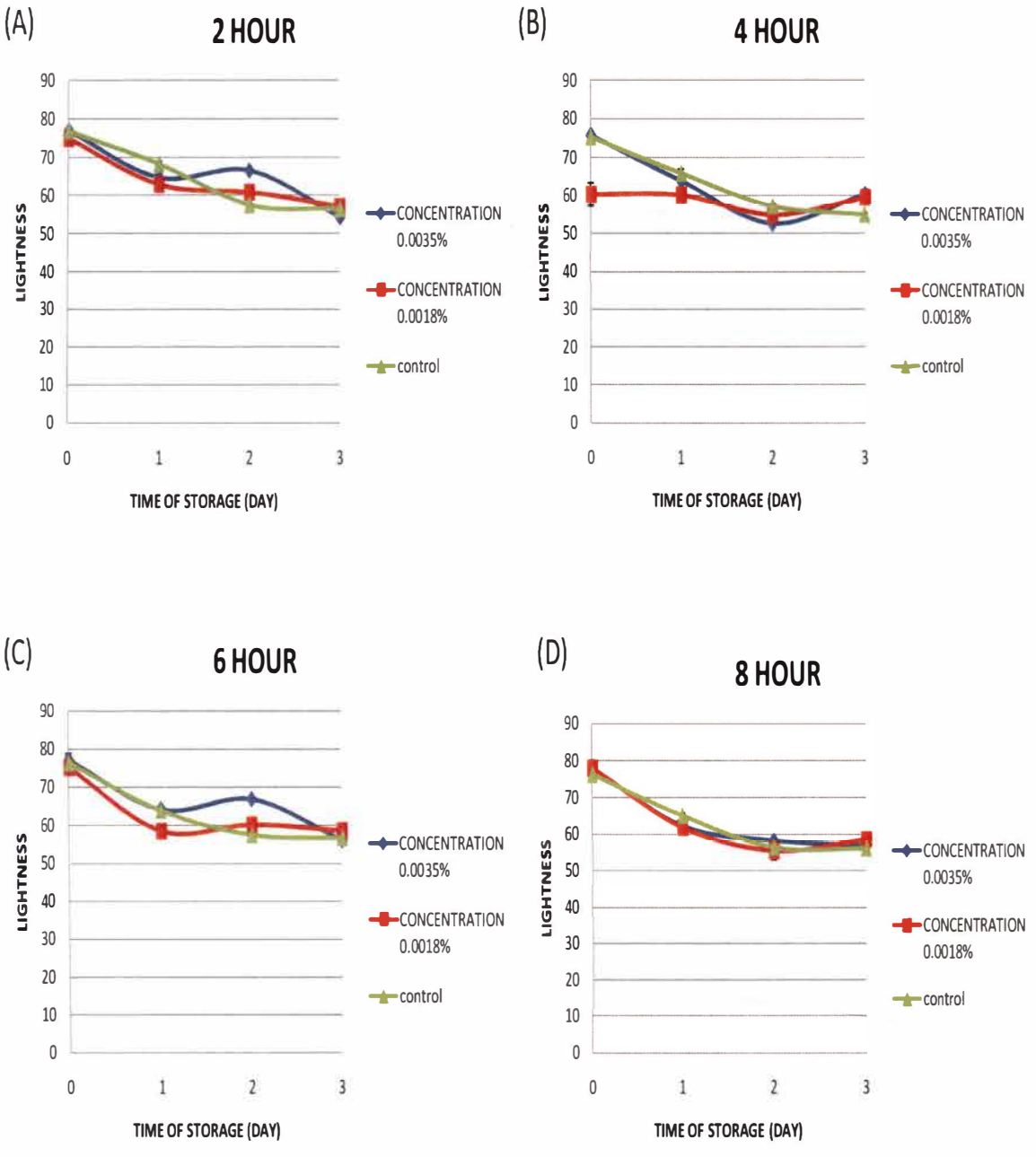

Figure 4.2: Lightness changes of bean sprouts after immersed in tartaric acid solution at a concentration of 0.0018 or 0.0035% for 2(A), 4(B), 6(C) and 8(D) hours and stored at ambient temperature of 28°C for three days.

4.3 Firmness of shredded cabbages

Figure 4.3 shows firmness changes of shredded cabbages exposed to 0.0035 or 0.0018% of tartaric acid solution with different time length of immersions and stored at ambient temperature for three days. All treatments showed a decrease in crunchiness during storage. There were significant differences in firmness of shredded cabbage immersed for different time length in 0.0035 and 0.0018% of tartaric acid solutions compared with control. On day three, shredded cabbages immersed in 0.0035% tartaric acid and distilled water (control) for two hours had significantly firmer texture compared to those treated with 0.0018% tartaric acid (Appendix C). However, treated cabbages and untreated cabbages had no significant difference when immersed for four, six and eight hours regardless of any concentrations of tartaric acid (Appendix C).

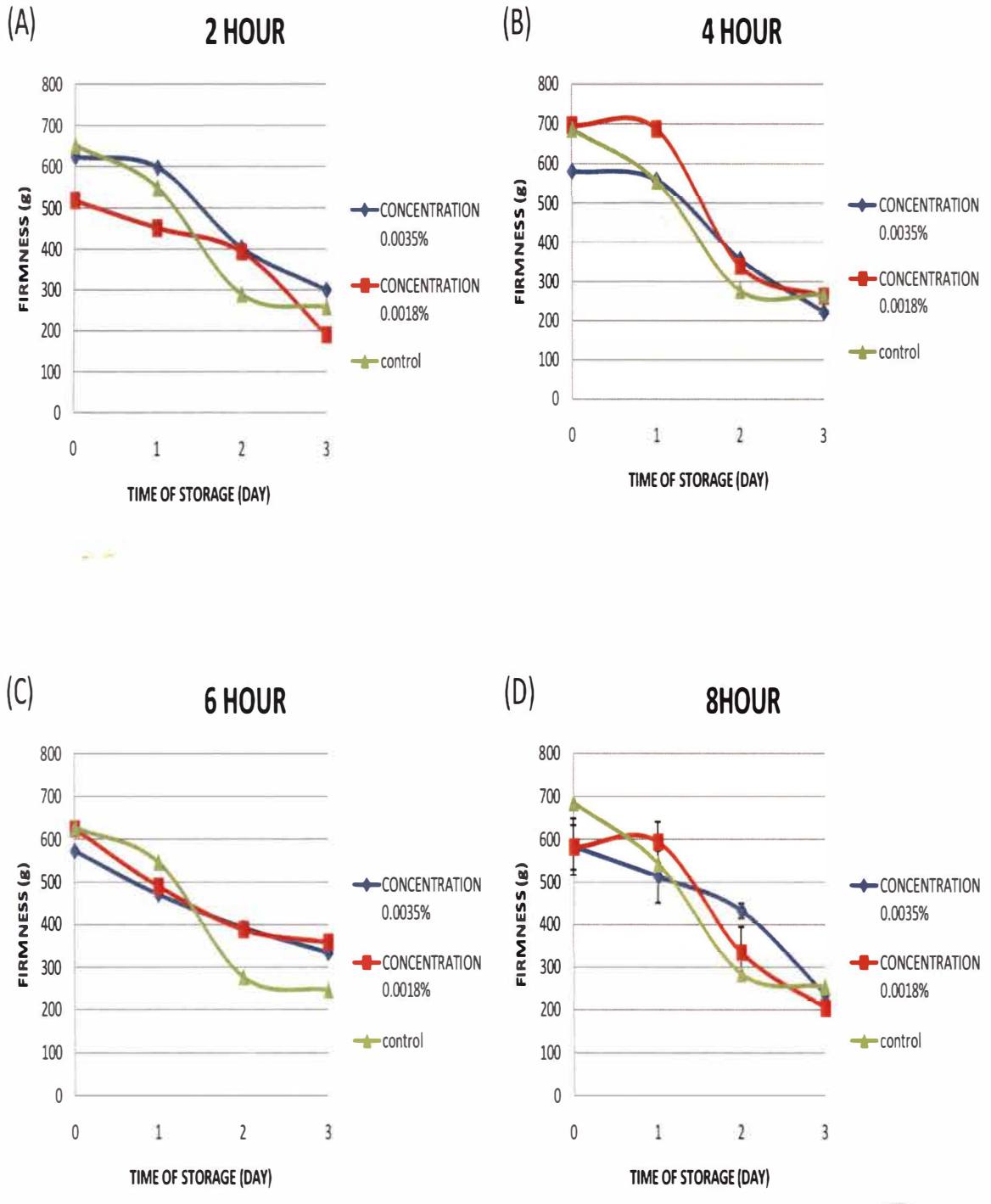

Figure 4.3: Firmness changes of shredded cabbages after immersed in tartaric acid solution at a concentration of 0.0018 or 0.0035% for 2(A), 4(B), 6(C) and 8(D) hours and stored at ambient temperature of 28°C for three days.

4.4 Lightness of shredded cabbages

Figure 4.4 shows lightness changes of shredded cabbages exposed to 0.0035 and 0.0018% of tartaric acid solution with different time length of immersion and stored at ambient temperature for three days. All treatments showed a decrease in lightness during storage. There were significant differences in lightness of shredded cabbage which immersed for different time length in 0.0035 and 0.0018% tartaric acid solutions compared with control shredded cabbages. On day three, in general, shredded cabbages immersed in 0.0035% and 0.0018% tartaric acid had significantly lighter color compared to control regardless of any immersion periods (Appendix D). Interestingly, for six hours of immersion in 0.0035% or 0.0018% tartaric acid, it is found that both treatments already had higher lightness as compared to control on day two. Therefore, it is suggested that shredded cabbages immersed in 0.0018 or 0.0035% of tartaric acid solution for six hours gave a better lightness than untreated shredded cabbages.

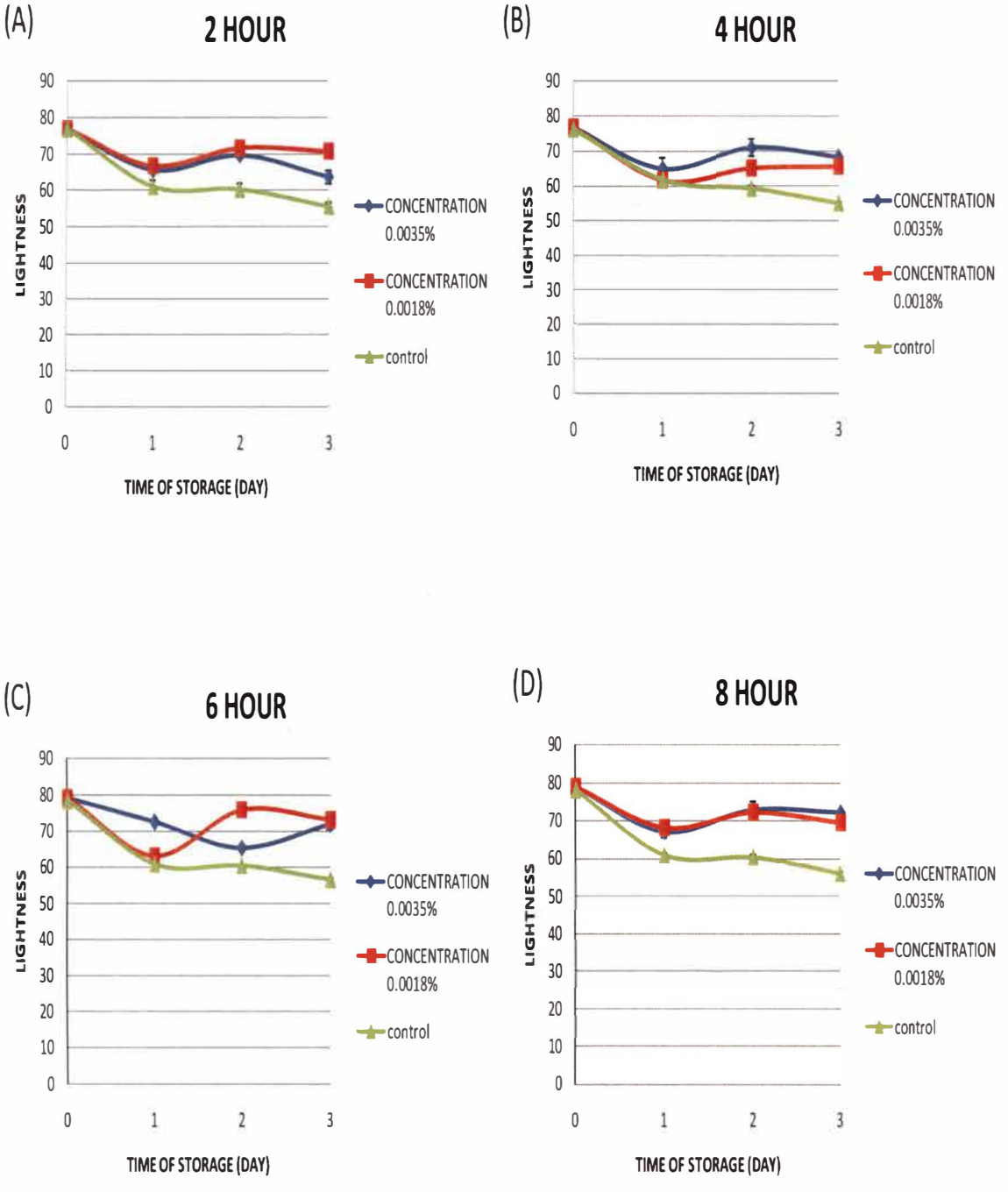

Figure 4.4: Lightness changes of shredded cabbages after immersed in tartaric acid solution at a concentration of 0.0018 or 0.0035% for 2(A), 4(B), 6(C) and 8(D) hours and stored at ambient temperature of 28°C for three days.

Tartaric acid acts as an anti browning agent which inhibit enzymatic browning that may cause the color of vegetables turn brown (Son et al., 2001). The present

study was carried out to examine effects of tartaric acid solution on firmness of bean sprouts but no scientific evidence has shown that it can assist in retaining firmness of vegetables. In spite of that, it has been demonstrated that phenolic compounds can play a role in vegetables texture even though only a small amount or quantity present in vegetables (Smith et al., 2003). Mostly, the levels of phenolics are very low in edible tissues. The main source of phenolic compound is from lignified cell types where lignin is a hydrophobic network with immersing strength. Besides, there is also simple phenolic compound such as ferulic acid which can be found in non-lignified cell and can cross-link the wall of polysaccharides. In other words, the texture of edible tissues especially vegetables is due to the existence of phenolic (Smith et al., 2003). Since tartaric acid is a member of phenolic compound group, therefore it is believed to exhibit the similar role in maintaining texture of edible tissues. Moreover, kojic acid, a member of phenolic compound group, is well known to be the inhibitor of enzymatic browning by binding with polyphenol oxidase enzyme on its active site (Janovitz-Klappet et al., 1990). This has been proven in a study conducted by Son et al. (2001). In this previous study, apple slices had been tested with seven natural substances which belong to the group of phenolic acids. Kojic acid has shown the highest potency among all phenolic acids tested. Therefore, it is unlikely that the phenolic compound in the cell wall of bean sprouts and shredded cabbages can be degraded by the enzyme since all the active site of the enzyme may have been filled with tartaric acid. Since tartaric acid is a member of phenolic compound group which is same with kojic acid, it is assumed that it has same role in maintaining the firmness of bean sprouts and shredded cabbages. However, according to comparison on cost chemical, it is found that the cost for applying kojic acid is very high compared to tartaric acid (Nor Azian, 2009). It is better to employ tartaric acid instead of kojic

acid even though kojic acid has the potency to prevent the activity of browning. The treatment with tartaric acid alone was able to prevent crunchiness loss of bean sprouts (Nor Azian, 2009).

Previous studies have noted the importance of tartaric acid as an anti-browning agent. Apple slices had been tested with seven natural substances which belong to the same group of tartaric acid (phenolic acids) as demonstrated by Son et al. (2001). Kojic acid has been shown to exhibit the highest potency among all phenolic acids tested. In the same study, twelve carboxylic acids were tested for their anti-browning activity on apples slices. Tartaric acid is one of the best inhibitors which resulted in only slight browning. These acids can inhibit the formation of enzymatic browning by different mode of actions. Tartaric acid is also used as antioxidant. Antioxidants are compounds that inhibit or prevent the oxidation reactions caused by free radicals, with or without oxidation enzymes that cause discoloration or browning of certain fruit and vegetable tissues and rancidity of fats (Sapers, 1993; Sherwin, 1990). This can affect the color or flavor of fruit and vegetable products. Furthermore, tartaric acid is one of the members of carboxylic acid. Hence, it is assumed to have anti-browning activity similar with other carboxylic acids. In the previous study, aromatic carboxylic acids of the benzoic acid and cinnamic acid series are polyphenol oxidase inhibitors, owing to their structural similarity to phenolic substrates (Krueger, 1955). Undissociated forms of these acids are capable of inhibiting polyphenoloxidase, through complexation with copper at the active site of the enzyme. The degree of polyphenol oxidase inhibition by carboxylic acids is pH dependent, and increases with a decrease in pH. Cinnamic acid and its analogues, *p*-coumaric, ferulic, and sinapic acids were found to be potent inhibitors of potato (Macrae and Duggleby, 1968) and apple polyphenol oxidases (Pifferi *et al.* 1974; Walker and Wilson, 1975). Cinnamic acid at

levels of 0.01 percent was observed to be effective in providing long-term inhibition of polyphenol oxidase in apple juice (Walker, 1976). Besides, Langdon (1987) reported that several chemical compounds such as ascorbic and citric acid inhibit enzymatic browning of potato slices. Oxalic acid is a natural component of a large number of plants such as spinach, broccoli, tomato and turnip (USDA/HMS, 1984) and appears to inhibit enzymatic browning. PPO has been widely studied in various fruits such as apple (Harel et al., 1964), grape (Harel and Mayer, 1971), litchi (Tan and Li, 1984) and plum (Lin et al., 1994), but little is known about bean sprouts and shredded cabbages. In the present study, bean sprouts and shredded cabbages treated with tartaric acid solution also have the encouraging effects on lightness and browning that is in line with previous studies on carboxylic acids.

Besides, there is a chance where bean sprouts and shredded cabbages have been infected by bacteria during transportation or production, thereby causing tissue softening of bean sprouts and shredded cabbages due to soft rot. This may have led to increased browning and reduced firmness of both bean sprouts and shredded cabbages. Bean sprouts typically have very high bacterial counts (Michard et al., 1993, Splittstoesser et al., 1983), because of the sprouting period at high temperatures. Bacterial communication signals, acylated homoserine lactones (AHLs) have been detected in a variety of different spoiled commercial food products, such as cold-smoked salmon (Gram et al., 1999), fish fillet, minced fish, turkey meat, vacuum-packed beef and bean sprouts (Bruhn et al., 2004, Gram et al., 2002). Furthermore, there were many gram-negative bacteria involved in food spoilage are capable producing AHLs (Ravn et al., 2001). The most important bacteria causing soft rot of vegetables and fruits are the gram-negative *E. caratovora* and pectinplytic strains of *Pseudomonas fluorescens* (Lund, 1982). Besides, the method of washing the bean

sprouts and shredded cabbages using distilled water alone before the treatment is not sufficient to kill the microorganisms. Hence, the rotting of bean sprouts continued even during the treatments. Tartaric acid plays an important role chemically by lowering the pH of fermentation to a level where many undesirable spoilage bacteria cannot live. Previous studies have demonstrated that phenolic compounds at high concentrations are toxic for the bacterial cell, which could cause inhibition on their growth (Reguant et al., 2000, Stead, 1993). It is likely that spoilage bacteria may not be able to survive in tartaric acid solution with low pH. In the previous study, there was acceptable reduction of diseases after fumigation with ozone treatment alone or ozone plus dipping in all oxalic acid, ascorbic acid, and citric acid for over 3 weeks in storage at 5 °C when compared with the control (Whangchai et al., 2005). As a result, the firmness of bean sprouts and shredded cabbages and remains crunchy.

The results of this study have revealed that 0.0035% tartaric acid is the best solution in reducing firmness loss and browning of both bean sprouts and shredded cabbages. Although, 0.0018% tartaric acid solution had a good effect on lightness shredded cabbages on day two when immersed for six hours as compared to two hours (Appendix D), 0.0018% tartaric acid solution had a bad effect compared to untreated cabbages on day one. Two hours of immersion period for both bean sprouts and shredded cabbages in tartaric acid solution is the best time length of immersion period for reduction of firmness loss and browning. In contrast, six or eight hours of immersion period cannot reduce the firmness loss and browning of both bean sprouts and shredded cabbages. This is because when bean sprouts and shredded cabbages were immersed in tartaric acid solutions for a long period, osmosis occurred and resulted in loss of firmness. Osmosis occurred in plant when water potential in plant cells are greater than outside, resulting in a net movement of water out of cell. Once

the water moves out from cell, it became soft and loss in firmness due to lack of water inside the cell. Hence, bean sprouts and shredded cabbages cannot maintain their firmness in 0.0018% of tartaric acid solution with four, six or eight hours of immersion period.

CHAPTER 5

CONCLUSION

5.1 Conclusion

The present study is designed to determine the effect of tartaric acid on firmness and browning of bean sprouts and shredded cabbages. In order to select the best treatment, two different concentrations of tartaric acid and four different immersion periods were assessed for their inhibitory activity on browning under ambient temperature of 28°C.

This study has shown that tartaric acid has the ability to inhibit firmness loss and browning of bean sprouts and shredded cabbages. The treatment that has significant effect in maintaining firmness while preventing browning of bean sprouts as well as shredded cabbage is 0.0035% of tartaric acid solution with the immersion period of two hours. This finding enhances the understanding of tartaric acid as a potential inhibitor for browning and loss in firmness especially on bean sprouts and shredded cabbage. In economic view, tartaric acid is suitable for usage because it is cost-effective.

5.2 Suggestions for further study

In order to study more about the effect of anti browning agents on browning and firmness of bean sprouts and shredded cabbages, further experiment can be conducted. Microbial contamination and growth on bean sprouts and shredded cabbages can occur easily. Shredded cabbages are minimally processed vegetables by shredding their tissues, natural protective barrier towards microbial attack are removed and produce a moist surface which is rich in nutrients that is superb medium for growth of microorganisms. This contamination will lead to soft rot bacteria on shredded cabbages as well as bean sprouts. These bacteria are capable of causing soft rot spoilage on shredded cabbage and bean sprouts thus causing degradation in texture of vegetables. Therefore, microbial growth analysis on bean sprouts and shredded cabbages need to be done in future.

Another experiment related to this study is determination of concentration of tartaric acid solutions which can reduce loss in firmness and browning on bean sprouts and shredded cabbages. In this study, tartaric acid solutions only showed effects on day two and day three (Appendix A, B, C and D), but no effects were observed on day one.

REFERENCES

Amiot, M.J., Tacchini, M., aubert, S. and Nicolas, J. 1992. "Phenolic composition and browning susceptibility of various apple cultivars and pear cultivars at maturity. *Bulletin Liaison Groupe Polyphenols* 16:48-52.

Ahvenainen, R. 1996. New approaches in improving the shelf-life of minimally processed fruit and vegetables. *Trends Food Science and Technology* 7:179-186.

Bourne, M. C. 1982. Food texture and viscosity: Concept and measurement. Academic Press. London. In: Bartz, J. A. and Brecht, J. K. Rev. ed. *Postharvest physiology and pathology of vegetables*. 2nd *ed* p. 297-301.

Brecht, J. K. 1995. Physiology of lightly processed fruits and vegetables. *Journal of Horticulture science* 30(1): 18-22.

Bruhn, J. B., Cristensen, A. B., Flodgaard, L. R. , Nielsen, K. F., Larsen, T. O. Givskov, M. and Gram, L. 2004. Presence of acylated homoserine lactones (AHLs) and AHL-producing bacteria in meat and potential role of AHL in spoilage of meat. *Application Environment Microbiology* 70:4293-4302.

Chiang et al., 1993 M.S. Chiang, C. Chong, B.S. Landry and R. Crete, Cabbage. In: G. Kalloo and B.O. Berg, Editors, *Genetic Improvement of Vegetable Crops*, Pergamon Press, New York (1993) pp. 100–152.

Coseteng, M. Y. and Lee, C. Y. 1987. Changes in apple polyphenoloxidase and polyphenol concentrations in relation to degree of browning. *Journal of Food Science* 52:985-989.

Duxbury, D. D. 1986. Sulfite alternative blend extends self life of fresh fruits, vegetables. Effective sulfite alternative without bleaching. *Journal of Food Processineg* 49:98-100.

Friedman, M. 1996. Food browning and its prevention: an overview. *Journal of Agriculture Food Chemistry* 44:631-653.

Gram, L., A. B. Christensen, L. Ravn, S. Molin, and M. Givskov. 1999. Production of acylated homoserine lactones by psychrotrophic members of the *Enterobacteriaceae* isolated from foods. *Application Environment Microbiology* 65:3458-3463.

Gram, L., Ravn, L., Rasch, M., Bruhn, J. B., Christensen, A. B. Givskov, M. 2002. Food spoilage interactions between food spoilage bacteria. *Internet Journal Food Microbiology* 78:79-97.

Harker, F.R. and P.W. Sutherland. 1993. Physiological changes associated with fruit ripening and the development of mealy texture during storage of nectarines. *Postharvest Biology Technology* 2:269-277.

Kader, A. A. 1992. In: A. A. Kader, ed., *Postharvest technology of horticulture crops.* University of California, Division of Agriculture and Resources, Publication 3311 p 15-20.

Laminkara, O. 2002. Enzymatic effects on flavor and texture of fresh cut fruits and vegetables. In: Laminkara, O. *Fresh cut fruits and vegetables.* Science Technology Market p. 125-185.

Langdon, T. T. 1987. Prevention of browning in fresh prepared potatoes without the use of sulfating agents. *Journal of Food technology* 41: 64, 66-67.
Lund, B. M. 1982. The effect of bacteria on post-harvest quality of vegetables and fruits, with particular reference to spoilage. Social *Application Bacteriology Symptom Service* 10:133-153.

Mathew, A. G. and Parpia, H. A. B. 1971. Food browning as a polyphenol reaction. *Journal of Advance Food Respiration* 19: 75-145.

Michard, J., N. Jardy, and J. L. Gey. 1993. Bacteriologie des pousses de "soja" (*Vigna radiata*). *Microbiology aliments Nutrition* 11:135-146.

Ravn, L., Christensen, A. B., A. B., Molin, S., Givskov, M. and Gram, L. 2001. Methods for detecting acylated homoserine lactones produced by Gram-negative bacteria and their application in studied of AHL-production kinetics. *Journal Microbiology Methods* 44:239-251.

Saltveit, M.E., 1997. Physical and physiological changes in minimally processed fruits and vegetables. In: Tomás-Barberán, F.A., Robins, R.J. (Eds.), Phytochemistry of Fruit and Vegetables. Proceedings of the Phytochemical Society of Europe 41. Oxford University Press, New York, NY pp. 205–220.

Saper, G. M.; Hicks, K. B.; Phillips, J. G.; Garzella, 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.

Sapers, G. M., Garzarella, L. and Pilizota, V. 1990. Application of browning inhibitors to cut apple and potato by vacuum and pressure infiltration. *Journal of Food Science* 55:1049-1053.
Sapers, G. M. and Miller, R. L. 1992. Enzymatic browning control in potato with ascorbic acid-2-phosphates. *Journal of Food Science* 57: 1132-1135.

Son. S. M., Moon, K. D. and Lee C. Y. 2001. Inhibitory effects of various anti browning agents on apple slices. *Journal of Food chemistry* 73: 23-30.
Splittstoesser, D. F., Queale, D. T. and B. W. Andaloro. 1983. The microbiology of vegetable sprouts during commercial production. *Journal of Food safety* 5:79-86.

Vamos-Vigyazo, L., Gajzago, I., Nadudvari-Markus, V. and Mihalyi, K. 1976. Studies into the enzymatic browning and the polyphenol oxidase complex of apple cultivars. *Confructa* 21: 24-35.

Vaughan and Geissler, 1997a J.G. Vaughan and C.A. Geissler, The new Oxford book of food plants, Oxford University Press, New York (1997) pp. 166–169.

Appendix A: Firmness of bean sprouts treated with tartaric acid at ambient temperature (28°C)

Treatment	Day 0	Day 1	Day 2	Day 3
0.0035% 0h	612.31±7.41^{a}	388.15±1.36^{a}	283.55±2.19^{b}	143.01±2.41^{a}
0.0018% 0h	623.25±1.44^{a}	395.72±2.10^{a}	276.57±2.06^{ab}	154.73±2.10^{b}
control 0h	624.06±2.93^{a}	385.16±2.94^{a}	270.76±1.60^{a}	144.08±2.32^{ab}
0.0035% 2h	560.15±35.74^{a}	485.88±38.80^{a}	367.14±18.48	124.35±41.53^{a}
0.0018% 2h	533.83±40.32^{a}	479.76±17.12^{a}	433.73±22.46^{b}	79.85±7.67^{a}
control 2h	629.70±10.32^{a}	396.43±7.52^{a}	286.14±2.37^{a}	142.31±1.82^{a}
0.0035% 4h	514.50±40.08^{a}	470.91±16.56^{a}	346.60±72.50^{a}	96.83±0.71^{b}
0.0018% 4h	491.134±57.66^{a}	444.18±66.80^{a}	256.78±42.32^{a}	74.10±1.49^{a}
control 4h	637.86±1.61^{a}	338.51±1.45^{a}	283.17±1.39^{a}	145.11±2.91^{c}
0.0035% 6h	467.54±89.89^{a}	427.03±85.10^{a}	249.15±46.85^{a}	107.04±9.60^{a}
0.0018% 6h	461.96±78.16^{a}	329.85±17.06^{a}	324.85±83.21^{a}	109.31±0.59^{a}
control 6h	641.95±2.00^{a}	350.85±1.20^{a}	285.48±2.90^{a}	148.64±1.55^{b}
0.0035% 8h	462.60±26.75^{a}	448.20±66.47^{a}	231.50±12.09^{a}	114.11±18.27^{a}
0.0018% 8h	440.36±30.92^{a}	376.10±20.74^{a}	359.51±17.52^{b}	170.43±23.36^{a}
control 8h	605.49±2.86^{b}	418.84±1.55^{a}	282.60±1.57^{a}	143.21±1.42^{a}

Each data point represents the mean of three replicates ±standard error. Different letters in the same column for each immersion period denotes a significant difference by the Tukey HSD test ($p<0.05$).

Appendix B: Lightness of bean sprouts treated with tartaric acid at ambient temperature (28°C)

Treatment	Day 0	Day 1	Day 2	Day 3
0.0035% 0h	77.90±0.58[a]	67.10±0.99[a]	57.65±0.71[a]	57.25±0.84[a]
0.0018% 0h	76.36±0.97[a]	67.44±0.94[a]	57.33±0.87[a]	57.23±0.46[a]
control 0h	76.40±0.58[a]	67.90±0.65[a]	56.82±1.ll a	54.84±0.52[a]
0.0035% 2h	76.42±0.83[a]	64.00±1.82[a]	66.06±0.3c	54.77±0.94[a]
0.0018% 2h	74.71±0.83[a]	63.62±2.12[a]	61.40±0.73[b]	57.64±0.47[a]
control 2h	76.29±0.47[a]	70.86±1.32[a]	57.03±0.78[a]	56.40±0.34[ab]
0.0035% 4h	75.76±1.61[a]	63.30±1.47[a]	52.80±0.82[a]	61.50±2.43[a]
0.0018% 4h	71.35±5.53[a]	60.43±0.38[a]	54.28±1.02[a]	58.40±0.94[a]
control 4h	74.98±0.43[a]	69.88±2.07[b]	56.36±1.13[a]	55.74±0.70[a]
0.0035% 6h	72.24±3.14[a]	64.03±0.94[a]	66.83±0.63[b]	56.00±1.85[a]
0.0018% 6h	73.26±2.28[a]	58.38±2.66[a]	60.07±2.25[a]	58.51±0.86[a]
control 6h	76.64±0.77[a]	64.65±0.67[a]	57.51±0.33[a]	56.73±0.62[a]
0.0035% 8h	72.51±2.89[a]	62.25±1.11[a]	58.19±0.90[a]	56.65±0.95[a]
0.0018% 8h	74.50±3.76[a]	61.77±2.02[a]	55.26±4.26[a]	58.53±1.66[a]
control 8h	77.25±1.09[a]	63.3±1.34[a]	58.39±1.06[a]	56.47±1.50[a]

Each data point represents the mean of three replicates ±standard error. Different letters in the same column denote a significant difference by the Tukey HSD test ($p<0.05$).

Appendix C: Firmness of shredded cabbages treated with tartaric acid at ambient temperature (28°C)

Treatment	Day 0	Day 1	Day 2	Day 3
0.0035% 0h	652.57±1.26[a]	548.12±1.70[c]	288.23±1.56[a]	256.46±2.97[a]
0.0018% 0h	651.12±0.55[a]	650.25±0.53[a]	285.85±2.98[a]	261.84±1.07[a]
control 0h	653.05±1.59[a]	583.50±1.55[b]	287.63±1.51[a]	263.17±1.48[a]
0.0035% 2h	647.23±123.14[a]	597.92±130.95[a]	403.27±48.63[a]	299.14±4.09[b]
0.0018% 2h	517.69±47.92[a]	450.39±63.65[a]	392.63±77.01[a]	189.13±26.76[a]
control 2h	652.90±1.30[a]	547.97±1.58[a]	288.19±1.60[a]	258.19±1.46[b]
0.0035% 4h	587.57±69.27[a]	558.49±80.78[a]	357.22±44.23[a]	220.17±23.14[a]
0.0018% 4h	695.83±127.27[a]	686.38±134.38[a]	338.70±72.66[a]	261.22±48.93[a]
control 4h	684.78±3.58[a]	554.36±4.04[a]	276.78±1.99[a]	267.55±4.40[a]
0.0035% 6h	572.91±26.94[a]	469.74±11.89[a]	392.43±54.95[a]	333.76±18.90[a]
0.0018% 6h	623.08±59.00[a]	488.75±63.21[a]	387.29±68.08[a]	357.30±63.85[a]
control 6h	628.13±1.40[a]	543.91±4.61[a]	276.56±2.29[a]	245.74±2.82[a]
0.0035% 8h	582.38±120.90[a]	512.25±112.40[a]	432.29±31.61[a]	235.61±16.03[a]
0.0018% 8h	644.62±94.98[a]	593.21±86.66[a]	333.38±111.77[a]	203.08±30.80[a]
control 8h	680.54±4.86[a]	547.53±2.18[a]	284.77±5.62[a]	255.46±2.78[a]

Each data point represents the mean of three replicates ±standard error. Different letters in the same column denote a significant difference by the Tukey HSD test ($p<0.05$).

Appendix D: Lightness of shredded cabbages treated with tartaric acid at ambient temperature (28°C)

Treatment	Day 0	Day 1	Day 2	Day 3
0.0035% 0h	75.71±0.87[a]	60.40±0.96[a]	61.50±0.81[b]	55.60±0.36[a]
0.0018% 0h	75.80±0.91[a]	62.53±0.87[a]	55.82±1.20[a]	56.51±0.77[a]
control 0h	76.62±0.47[a]	60.97±1.08[a]	56.84±0.95[a]	54.60±1.37[a]
0.0035% 2h	76.42±0.83[a]	65.15±0.86[a]	69.64±1.77[a]	63.60±3.31[ab]
0.0018% 2h	75.38±1.10[a]	64.42±1.79[a]	71.84±1.94[a]	69.98±2.24[b]
control 2h	76.29±0.47[a]	61.63±3.24[a]	62.17±2.98[a]	56.33±1.96[a]
0.0035% 4h	76.42±1.33[a]	63.28±5.88[a]	69.40±4.51[a]	66.95±1.53[b]
0.0018% 4h	72.20±2.66[a]	61.35±2.36[a]	63.91±3.57[a]	63.25±1.123[b]
control 4h	75.31±0.62[a]	68.55±3.39[a]	57.02±1.50[a]	55.74±0.70[a]
0.0035% 6h	75.78±1.72[a]	70.31±1.75[b]	67.30±1.86[b]	71.25±2.49[b]
0.0018% 6h	76.81±1.12[a]	59.64±2.02[a]	76.34±1.44[c]	71.79±1.70[b]
control 6h	77.51±0.42[a]	63.56±1.47[b]	60.09±0.28[a]	56.64±0.71[a]
0.0035% 8h	75.86±1.59[a]	65.98±2.85[a]	69.27±4.03[a]	71.80±0.28[b]
0.0018% 8h	77.46±0.77[a]	65.83±1.18[a]	72.61±3.42[a]	69.32±1.28[b]
control 8h	77.14±0.55[a]	62.37±0.87[a]	62.11±1.52[a]	55.31±0.84[a]

Each data point represents the mean of three replicates ±standard error. Different letters in the same column denote a significant difference by the Tukey HSD test ($p<0.05$).

Appendix E: Observation of bean sprouts and shredded cabbages treated with tartaric acid at ambient temperature (28°C)

Treatments / samples	Bean sprouts	Shredded cabbbages
0.035%		
0.00185		

Control		

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EFFECTS OF TARTARIC ACID ON BROWNING AND FIRMNESS OF BEAN SPROUTS AND SHREDDED CABBAGES WITH DIFFERENT IMMERSION PERIOD - NORAINI BT MOHAMAD DAUD