The Effectiveness of Chitosan Coating with Different Concentrations and Temperature Storages on Brinjal (*Solanum melongena*)

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A report submitted in fulfilment of the requirements for the degree of Bachelor of Applied Science (Agrotechnology) with Honour

Faculty of Agro-Based Industry

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DECLARATION

I hereby declare that the work embodied in this report is the result of the original research and has not been submitted for a higher degree to any universities or institutions.

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I certify that the report of this final year project entitled "The Effectiveness of Chitosan Coating with Different Concentrations at Different Temperature Storage of Brinjal (*Solanum melongena*)" by Siti Salwani Binti Zainun, matric number F15A0222 has been examined and all the correction recommended by examiners have been done for the degree of Bachelor of Applied Science (Agrotechnology) with Honours, Faculty of Agro-Based Industry, Universiti Malaysia Kelantan.

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Supervisor:

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The Effectiveness of Chitosan Coating with Different Concentrations and Temperature Storage on Brinjal (*Solanum melongena*)

ABSTRACT

The study focuses on determining the effectiveness of chitosan coating with different concentrations at different storage temperatures on brinjal (*Solanum melongena*). A primary concern of brinjals is that the shelf life of the brinjal is very short. An edible coating is an eco-friendly technology that used in many industries including the food industry. There are many edible coatings available in the industry. Chitosan coating is one of the edible coatings used in order to prolong the shelf-life of the brinjals. An edible coating is increasingly important in the post-harvest technology to reduce the losses. This study investigates the factors that determine the effectiveness of the chitosan which is the concentration and temperatures of the storage. Different concentrations of chitosan are 1.0%, 1.5% and 2.0%. Different temperatures are ambient temperature (30±2) and cool storage. Four parameters were examined which are colour, weight loss, firmness/texture, and Total soluble solids (TSS). Results show that 2.0% is better at ambient temperature and 1.0% better at cool storage.

Keywords: Brinjals, chitosan, storage temperatures, shelf-life

Keberkesanan Salutan Kitosan dengan Kepekatan yang Berbeza pada Suhu Penyimpanan yang Berbeza ke atas Terung (*Solanum melongena*)

ABSTRAK

Kajian ini menumpukan pada penentuan keberkesanan salutan kitosan dengan kepekatan dan suhu penyimpanan yang berbeza pada terung (*Solanum melongena*). Kebimbangan utama bagi terung adalah bahawa jangka hayat terung adalah sangat singkat. Salutan yang edibel adalah teknologi mesra alam yang digunakan dalam banyak industri termasuk industri makanan. Terdapat banyak salutan edibel dalam industri. Salutan kitosan adalah salah satu salutan yang edibel untuk memanjangkan jangka hayat terung. Salutan edibel semakin penting dalam teknologi lepas tuai untuk mengurangkan kerugian. Kajian ini menyiasat faktor-faktor yang menentukan keberkesanan kitosan yang merupakan kepekatan dan suhu penyimpanan. Kepekatan kitosan yang berbeza adalah 1.0%, 1.5%, dan 2.0%. Suhu yang berbeza adalah suhu ambien (30 ± 2) dan suhu sejuk. Empat parameter diperiksa iaitu warna, penurunan berat terung, keanjalan/tekstur, dan jumlah pepejal terlarut (TSS). Keputusan menunjukkan bahawa 2.0% kepekatan lebih baik pada suhu ambien dan 1.0% kepekatan lebih baik pada suhu sejuk.

Kata kunci: Terung, kitosan, suhu, jangka hayat terung

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LIST OF SYMBOL ABBREVIATION

<	-	Less than
>	-	More Than
g	-	Gram
%	-	Percentage
^{0}C	-	Degree Celcius
M	-	Molar
Ch	-	Chitosan
TSS	-	Total soluble solid
w/v	-	Weight/Volume
ml	-	Millilitre
L	-	Litre

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Post-harvest losses are not new issues in the world anymore because the number of post-harvest losses increasing from days to days. Every developing country faced the same problem. Post-harvest losses of fruits and vegetables keep occurring because the characteristics of the fruit and vegetables itself are very perishable. Some of the horticulture crops have a high moisture content that easily to deteriorate because they are biologically active. Biochemical activities like transpiration, ripening and respiration will cause the deterioration to occur faster. Besides biological activity other factors like mechanicals injury, poor handling method and packaging can cause post-harvest losses to fruits and vegetables.

This brinjal include (*Solanum melongena*) which is also known as eggplant and aubergine in other countries, belong to the Solanaceae family. Brinjal is known as fruit but people consume it as a vegetable. The structures of brinjal is a bit hardy and have tough skin, by observing based on the physical the brinjal looks like it is a very tough fruit and able to adapt in tough condition. However, brinjals are actually a quite perishable fruit because it only can stay 3 days at room temperature (Singh et al., 2016) and seven days or one week in the refrigerator at 10 ^{0}C to 12 ^{0}C (Cantwell and Suslow, 2009).

Post-harvest losses of brinjal can occur during transporting it from one place to another place, especially to the far place. The supply chain including wholesaler, retailer, and lastly to the customer who is the one that will buy and use the brinjal. The quality attribute of the brinjal can decrease due to the time of the transport operation. The appearance or the physical condition which can be observed clearly will influence the customer for consuming it. The customers that focus on the appearance and aesthetic value of the brinjal will choose the brinjal with the best appearance. Commonly, the brinjal will become dry, wrinkle and brown spot will show after a few days or if the brinjals expose to the heat. The suitable temperature storage and coating that apply to the brinjal can reduce the damage to the brinjal and can increase the shelf-life of the brinjal.

The definition of an edible coating is the layer of material that coat on the surface of fruits and vegetables. It is edible and safe to be consumed and can provide a barrier to oxygen and microbes to the external source. Edible coating or also known as edible films are used in the food industries for so long in order to preserve the food products. It is a common method or commercially used to preserve or longer the shelf life of the fruits or vegetables. An edible coating is an environmentally friendly technology that can be applied to many types of fruits and vegetables. It is applied to fruits and vegetable to control biochemical activities like moisture transfer, oxidation process and gas exchange process (Dhall, 2013).

The examples that edible coating use in the worldwide are gums, alginate, pectin, carrageenan, agar, aloe vera and chitosan. Gums are known as polysaccharides contain sugars. There were three parts of gums which are exudate gums, extractive gums, and microbial fermentation gums. Alginate is made of brown seaweed that contains salts of alginate acid. Pectin is a polysaccharide that derived from plants but it not good moisture barrier for high moisture fruit. Agar gum commonly comes from red seaweed. Aloe vera is used the aloe gel in the aloe vera leaves. Lastly, chitosan is made up of chitin from crustacean animal shells.

After cellulose, chitosan is the common non-toxic and natural product that uses as an edible coating. Chitosan already appears as a good coating even though without adding any types of antioxidants. Chitosan has a good oxygen barrier and carbon dioxide permeation. Besides chitosan also act as an antimicrobial against microorganisms. The coating that derives from chitosan is very clear in colour or transparent, shiny and smooth on the surface. The chitosan has great antimicrobial properties that make it used in the food industry (Elsabee & Abdou, 2013). The experiment is conducted to recognize the suitable concentration of chitosan to be applied to the brinjal in order to prolong the shelf-life of the brinjal. The quality attributes of the brinjal are the parameters to know the effectiveness of chitosan at different concentration. Chitosan effectiveness with different concentration will be measured in different temperature storage. Quality attributes that will be analysed are colour, weight loss, firmness or texture analysis, and total soluble solids (TSS).

1.2 Problem Statements

Brinjal is a nutritious and unique vegetable that people consume it regularly. The structure of the brinjal with purple colour looks interesting. Brinjal appears to be hardy and has tough skin but actually, brinjal is quite perishable. Post-harvest loss of brinjals has occurred from harvesting period to ultimate consumer level because it undergoes physicochemical changes during the whole process of harvesting, storage, handling, transportation and marketing. Because of the physicochemical changes, the quality of brinjals deteriorating and lose weight. The shelf life of brinjal is very short and only can keep the freshness until the third days at the room temperature and if refrigerated, it will able to last for a week. Common methods used to control post-harvest losses in brinjals are by precooling after harvest, cleaning and disinfection and refrigerator storage. The main issue is that getting an effective and suitable chitosan concentration to be coated on the brinjal to aim the longer shelf life of the brinjal.

1.3 Objectives

1. To determine the suitable concentration of chitosan coating in prolonging the shelf life of the brinjal.
2. To determine the effectiveness of chitosan coating with different concentration at different storage temperature for 12 days.

1.4 Significant of Study

There are many types of edible coating applied in the food industry in order to increase the shelf life of the fruits and vegetables. Chitosan appeared as a commonly used coating in the industry.

The study is conducted in order to determine the suitable concentration of chitosan that will be more effective in increasing the shelf life of the brinjal. Chitosan on the surface of brinjal minimizes the microbial infection and penetration to avoid the damage of the brinjal. The suitable storage temperature is one of the factors that can increase the shelf life of the brinjal and maintain the quality of the vegetable.

By applying the right concentration of the chitosan on the brinjal and at the same time know which temperature is most suitable for the coating it will help to increase the shelf life of brinjal more efficiently. The quality of the brinjal can be controlled much better and the post-harvest loss of brinjal will reduce.

CHAPTER 2

LITERATURE REVIEW

2.1 Brinjals

2.1.1 Taxonomy of Brinjals

Kingdom - Plantae

Subkingdom - Viridiplantae

Infrakingdom Streptophyta – land plants

Superdivisio - Embryophyta

Division Tracheophyta – vascular plant

Subdivision Spermatophytina – spermatophytes, seed plants

Class - Magnoliopsida

Superorder - Asteranae

Order - Solanales

Family - Solanaceae – nightshades, solanacées

Genus Solanum L. – nightshade

Species - Solanum melongena

Common name - Brinjal/eggplant

(Integrated Taxonomic Information System, n.d.

Figure 2.1: The picture of brinjals.

(Source: www.rareseeds.com, n.d.)

2.2 Nutritional Value of Brinjal

The content of protein was variable in brinjal but in low amount. The content of carbohydrates available in brinjal ranged between 2.99 and 4.19 mg 100 g−1. Glucose and fructose are the main sugar available in the brinjal. The fibre content was the most variable trait. Acids contents in the brinjal are dehydroascorbic acid and ascorbic acid. The amount of ascorbic acid is lower than the amount of dehydroascorbic acid. Lastly, the total of phenolics compound is average thirty-nine-fold higher than vitamin C content (San José, Sánchez, Cámara, & Prohens, 2013).

2.3 Edible Coating

Edible coatings or films are known as very thin materials because commonly the thickness of the films or coatings are less than 0.3 mm. the materials used in the producing the edible coatings must follow the laws and regulations made by the government. Besides, the materials used must be clean and hygiene and safe to be consumed for humans. Edible coatings must fulfil their characteristic that it will not disturb or destroy the quality of the product that coated with the coatings (Parreidt, Müller, & Schmid, 2018)

Problems and obstacles in the food industry that causes losses of the fruit and vegetables can be overcome by using edible film and coatings that suitable for the product. The functions of the edible coatings are to maintain the moisture in the products, improve the structure of the membrane and retain volatile compounds. Besides, aesthetic appearance like the colour and glossiness can be maintained because edible coatings or films minimize the physical damage on the fruit and vegetables. Some scars from the small injury can be hidden and the appearance will maintain in a good quality to attract consumers (Parreidt, Müller, & Schmid, 2018).

Edible films and coatings are used widely because of the specific reasons like the product especially the perishable products like fruit and vegetables tend to expose to the injury in many stages. The stages are from the production phase to transportation and lastly during storage. The edible coatings can help to lessen the risk of the products from getting any injury from the process involved before reach to the consumers. Even though edible films is already good to protect the products but with joining non-edible packaging that hygiene and clean can be more useful and safer in order to maintain the quality of the fruits and vegetables (Parreidt, Müller, & Schmid, 2018).

Many factors can cause damages to the fruits and vegetables along the process from the field until reaching the consumer. The damages will degrade the quality of the fruit and the vegetables. Because of the damages that occur, edible coatings and films are provided to protect the fruits and vegetables from damage. The most important thing or the main function of the edible coatings is to ensure to prolong the shelf life of the product so that the product can be kept in good quality along the process before reach the consumer. other functions of edible coatings that make it interesting are, the colour changing on fruits and vegetables like the products change to brown colour, loss the original flavour and change the natural colour of the product from the field (Raghav, Agarwal, Saini, Vidhyapeeth, and Vidhyapeeth, 2016).

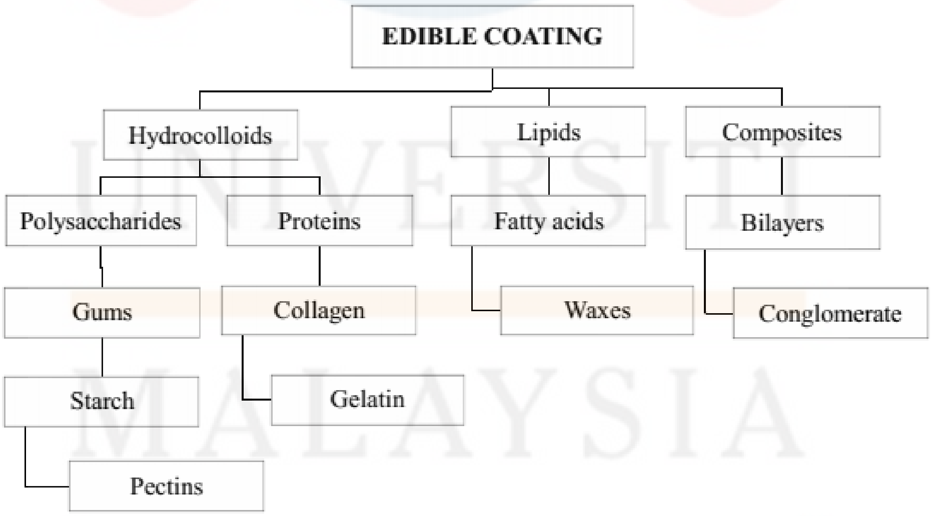

Figure 2.2: Different types of edible coating

(Sources: (Raghav, Agarwal, Saini, Vidhyapeeth, and Vidhyapeeth, 2016))

An edible coating is one of the common methods in order to preserve or longer the shelf life of the fruit and vegetables. Post-harvest handling mostly involved edible coating process. An edible coating can be used in many types of coating. The edible coating can control moisture transfer, gas exchange or oxidation processes and it is an environmentally friendly technology applied in products. The advantage of using edible films and coatings is that several active ingredients can be changed into the polymer matrix and consumed with the food, thus safety, nutritional and sensory attributes of fruit can be enhanced. The edible coating technology is not successful in all cases. The control of internal gas composition in the products can guarantee the success in using the edible coating (Dhall, 2013).

There are varies the type of methods in order to apply the edible coatings and films. The method commonly used is dipping because it is very useful and able to be applied easily. The most common method used is dipping because the methods are easier and can decrease the loss. Many fruits and vegetables can be dip together at the same time with big amount depend on the size of the beaker used to prepare the coatings. Besides dipping methods, other methods like spraying, brushing and extrusion also applied for the fruit and vegetables. Most of the methods applied are suitable for the product. For example, if tomatoes the dipping methods can be used and for leafy vegetables spraying method is more practical. All the methods applied are beneficial for suitable types of the product that needs to be coated (Raghav, Agarwal, Saini, Vidhyapeeth, and Vidhyapeeth, 2016).

People or industrial people choose to use edible coatings as their methods in prolonging the shelf life of fruits and vegetables and at the same time to make sure their product stay in good condition during storage time because there are many advantages that beneficial to use. The advantages are very common and settle most of the problems that can cause deterioration in the quality of the fruits and vegetables. The colour of the products can be maintained the same for a long time and keep the best appearance so that the market of the products will not drop. Besides, the flavour will not runoff and the aromatic flavour from the fruit can be kept long along the total soluble solids or sugar content in the products. Besides appearance and aroma, the taste also is one of the qualities that need to be protected. By using edible coatings and films, the appearance, aroma and the taste of the products can be protected and preserved for a longer time. Weight loss and shrinkage of the fruits and vegetables clearly shown on the appearance of the product, these factors occur due to the exposed to the environment and at the same time because of the storage time. An edible coating can help in slowing the process of losing moisture in the fruits and vegetables to make sure the weight loss is slower and the firmness can be maintained for a longer time. Disadvantages of the edible coatings and films cannot be avoided because of some of the edible coating materials used from the materials that can attract and support microbial growth. Besides if the layer for coating is not suitable or too thick, many physicochemical chemical processes cannot be done properly like the ripening process will become too slow because of the respiration process very slow. The process of respiration that too slow and ripening will wear off the original taste of the products (Raghav, Agarwal, Saini, Vidhyapeeth, and Vidhyapeeth, 2016)

2.4 Chitosan Coating

Chitosan is a linear polysaccharide consisting of (1, 4)-linked 2-amino-deoxy-β-D-glucan, is a deacetylated derivative of chitin. After cellulose, chitosan is the second most abundant polysaccharide found in nature (Ren Yinzhe, 2013). Chitosan coating has been applied in the preservation of fresh fruit and vegetables for so long. An edible coating is a cover to the surface of fruits and vegetables. The chitosan on the surface of the fruit and vegetable was applied during the post-harvest stage and the coating will protect the fruits and vegetables by control the respiration rate, restrain the weight loss rate a, and higher firmness has remained. Furthermore, chitosan coating is effective against microbes and can reduce decay (Ren Yinzhe, 2013).

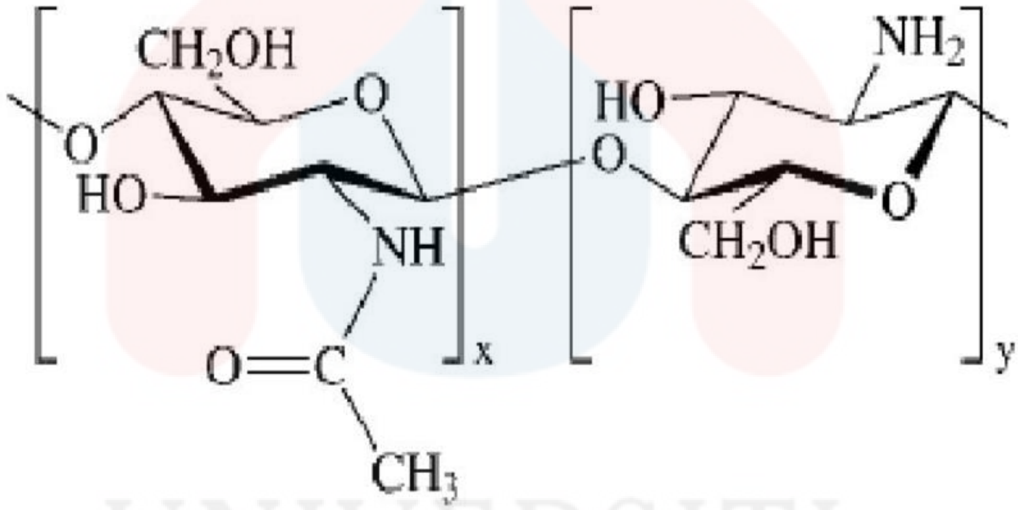

Figure 2.3: Chemical Structure of Chitosan

(Source: (Ibrahim & El-Zairy, 2015))

Chitosan is widely used nowadays because it is known as one of the safe coatings that can be applied to the fruits and vegetables. Besides chitosan also work very well with the other antimicrobial agent that caused it famous and favourable to the users. The compatibility of the chitosan and other agent is very beneficial and the product from the mix works very well (Guerra et. al, 2016).

Chitosan-based coating work very well in maintaining the membrane cell of the fruits and vegetables because the respiration rate in the fruit and vegetables slow down a little with the presence of chitosan coating. the slower process of respiration rate will control the ripening process at the same time will make sure the fruit and vegetables will ripe slowly and the biochemical content like sugar and nutrition will be kept longer in the fruits and vegetables. The slower rate of ripening will help to slow down the decay process and with the decaying process is slow, the fruits will not run off with the good odour and avoid the fruits and vegetables become stinks (Xing et. al, 2010).

Velickova et al. (2013) gave the best example with their research that the chitosan-beeswax coating could slow down the respiration rate and reduce the senescence of strawberries. Besides, Waewthongrak, Pisuchpen, and Leelasuphakula (2015) stated that the combination of the application of chitosan and the crude extract from the culture medium of *Bacillus subtilis* can protect citrus fruit from decaying at the fast rate. The process of decay become slower and the shelf life of citrus is prolonged. Furthermore, other prove are by Kaya, Asan-Ozusaglam, and Erdogan (2016), they expressed that the application of chitosan and acetic acid could extend the shelf life of kiwifruit berries. Moreover, Duran et al. (2016) indicated that the quality of strawberries could be maintained by chitosan coatings with nisin, natamycin, pomegranate and grape seed extract.

Microbial activities will occur on the fruits and vegetables at the suitable condition for the microbes to grow. Mostly the fruits and vegetables are easily affected and infected by the microbes. Chitosan has antimicrobial mechanism due to the positive charge molecules present in the chitosan while the microbial agents with negative charge. The difference charges from the chitosan and microbial agents make that chitosan able to fight the microbial agents from infected the fruits and vegetables. Besides, it might be due to the toxins produces from the chitosan that prevent the microbial mechanism from growing (Wang, Wu, Quin, and Meng, 2013).

Aquatic	Terrestrial	Microorganisms
Crustaceans	Arthropods	Fungi (cell walls)
Crab	Spiders	Ascomydes
Chionoecetes opilio	*Geolycosa vultuosa*	*Mucom rouxii*
Podophthalmus vigil	*Hogna radiate*	Blastomycota
Paralithodes amtschaticus	*Nephila edulis*	Blastocladiaceae
Carcinus mediterraneus		Chytridiomycota
		Chytridiaceae
	Scorpionxs	Protista
	Mesobuthus gibbosus	
Water lobster		Brown algae
Crayfish		Planta
		Green algae
Prawn	Beetles	
Aristens antennatus	*Bombyx mori*	
	Holotrichia parallela	
	Leptinotarsa decemlineata	
Krill	Cockroaches	
Daphnia longispina		
Anax imperator		
Hydrophilus piceus		
Notonecta glauca	Brachiopods	
Agabus bipustulatus	*Lingula seta*	
Asellus aquaticus		
Mollusca		
Squid pens		
Loligo sp		
Todarodes pacificus		
Coelenterata		

Figure 2.4: Sources of chitin and chitosan from various aquatic and terrestrial organisms.

(Sources: (Sharif et al., 2018))

Ripening and fruit senescence in peach is a major issue that affects their economic value. However, treatment with chitosan resulted in a significant increase in antioxidant enzyme activity, senescence arrest, delayed fruit ripeness, and maintenance of shape and colour (Ma, Yang, Yan, Kennedy, and Meng, 2013). In kiwifruit, the high molecular weight of chitosan was found to be effective in increasing the shelf life, fruit firmness, and other quality parameters (Drevinskas et al., 2017). It is clear from the above references that chitosan is involved in improving the physical structure and shelf life and maintaining the quality of post-harvest stored fruits.

CHAPTER 3

MATERIALS AND METHODS

3.1 Sources of Materials

Brinjals (*Solanum melongena*) were bought at Tanah Merah, Kelantan. The brinjals were in size classification of M. The size classification for M from Federal Agriculture and Marketing Authority Malaysia (FAMA) is the brinjals were 101 g to 200 g in weight and 11 cm to 20 cm in length. The brinjals were in uniform colour, without physical damage and infection by pest, diseases and fungal infections.

3.2 Methodology

3.2.1 Chitosan Coating Formulation

Acetic acid with 1% (v/v) concentration and chitosan powder were prepared by the laboratory in University Malaysia Kelantan, Jeli Campus. Different concentration of chitosan used are 1.0%, 1.5% and 2.0%. Based on Zahoorullah, Dakshayani, Swaroopa Rani and Venkateswerlu (2017) 1.5% (w/v) of chitosan and 1% (v/v) of lactic acid or 1% (v/v) acetic acid were used in their experiment to know the effectiveness of the chitosan coating on brinjals.

1.5% (w/v) chitosan solution was prepared by adding 1% acetic acid. 1.5 g of chitosan powder was added to 100 ml acetic acid solution. The magnetic stirrer with temperature 40 ^{0}C was used to stir the mixture until the chitosan fully dissolved (Zahoorullah, Dakshayani, Swaroopa Rani and Venkateswerlu, 2017). For 1% (w/v) concentration, 1.0 g chitosan powder dissolved in 100 ml acetic acid solution. For 2% (w/v) concentration, 2.0 g chitosan powder dissolved in 100 ml acetic acid.

Each solution with 1.0%, 1.5% and 2.0% concentrations were prepared into 300 ml. For 1.0% solutions, 3 g chitosan powder was added in 300 ml acetic solution with 1.0% concentration. While for 1.5% concentration, 4.5 g chitosan powder was added into 300 ml acetic acid solutions and for the 2.0% concentrations, 6 g of chitosan powder were added into the acetic acid solutions. The process for mixing and preparing the chitosan solutions was same by heating the solutions at 40^{0}C by using magnetic stirrer.

3.2.2 Coating Application

The chitosan solutions were prepared according to the concentrations needed in the experiment. Brinjals were dipped in the chitosan solutions at concentrations 1.0% 1.5%, and 2.0%. The brinjals were dried for 1 hour at room storage before keeping it at different temperature storage. The brinjals without any coating were stored at different temperature storage as a control. The brinjals were observed for every 3 days until 12 days based on the colour, firmness and weight and TSS (Zahoorullah, Dakshayani, Swaroopa Rani and Venkateswerlu, 2017).

3.3 Different Storage Temperatures

Two different storage temperatures were used, the first storage was room/ambient temperature around (30±2) ^{0}C and in the cool storage (refrigerator) with 7 ^{0}C, the temperature of the refrigerator was set up to 7 ^{0}C (Amanullah et al., 2016).

3.4 Quality Assessment

3.4.1 Colour

Colour changes were measured by using the Minolta chromameter (model CR-400X Minolta Camera Co. Ltd., Japan) every three days. The chromameter read three scopes which are L, a, and b. L is indicated to the lightness where black is L* = 0 while white L* = 100. a* is indicates of redness to greenness where red is a* = 100, grey a* = 0 and green a* = -100. b* indicates the yellowness to blueness where yellow b* = 100 and blue b* = - 100. Hue angles were calculated by the formula (h = - tan b*/a*). Hue angle readings determined the basic colours.

3.4.2 Firmness

Firmness was calculated by using the Brooklyn Texture Analyser by using force in gram. Firmness was performed by using TA 39/1000 (used probe TA39 of TA-MTP for fruit) manually through remote control by directing the machine to the computer. Every three days the reading was taken. The test type of texture pressure analyser (TPA) was set with the speed of 5mm/s. The firmness of the first peak on the graph when the probe penetrated the surface of brinjals was noted and the average readings were calculated.

3.4.3 Weight Loss

Weight loss was measured by weighing brinjals at the beginning, just after coating and drying, and thereafter every three days during the storage. Weight loss was expressed as the percentage loss of the initial total weight and of everyday weight (Zahoorullah, Dakshayani, Swaroopa Rani and Venkateswerlu, 2017).

3.4.4 Total soluble solids (TSS)

The brinjals were prepared into the juice then the TSS was tested by using a refractometer. The percentage soluble solids were measured in degrees Brix (^{0}Brix) (Magwaza & Opara, 2015).

3.5 Data Analysis

There were three replications used in this experiment and the design is complete randomized design (CRD). Two-ways ANOVA was used to analyse the results. Tukey HSD was used to compare mean among the treatments and temperatures. The p-values less than 0.05 ($p < 0.05$), significant value due to the difference were obtained.

3.6 Experimental Design

0% concentration of chitosan was acted as control. Chitosan solution was prepared based on the respective concentrations (1.0%, 1.5% and 2.0%). The solution for 1.0% was prepared by adding 1 g of chitosan powder into 100 ml of 1% acetic acid solution. For 1.5% used 1.5 g chitosan powder and for 2.0% used 2 g chitosan powder. All of the chitosan powders were mixed into 100 ml of 1% acetic acid solutions.

↓

The brinjals was washed by tap water and dried.

↓

After the brinjals fully dry, the brinjals were dipped in the chitosan solutions for 5 minutes and dried for 1 hour at room temperature (Zahoorullah, Dakshayani, Swaroopa Rani and Venkateswerlu, 2017).

↓

The brinjals were stored in two different storage temperatures, ambient temperature and 7 ^0C in cool storage.

↓

The brinjals were observed every 3 days based on colour, firmness, TSS and weight.

↓

Data was analysed in two-way ANOVA

Figure 3.1: Flowchart of research activities

CHAPTER 4

RESULT AND DISCUSSION

4.1 Effect of Different Concentration of Chitosan on Hue Angle

For ambient temperature, based on the Figure 4.1.1 the uncoated brinjals ripen faster than coated brinjals and the changes seemed to undergo fluctuation with rapid changes from day 9 to day 12. At day 12, the chitosan concentration of 2.0% shows the lowest hue angle while control or uncoated brinjals show the highest value of hue angle. The treated brinjals with 2.0% concentration of chitosan were the best treatment in detaining the deterioration at day 12.

Ninio, Lewinsohn, Mizrahi, and Sitrit (2003) stated that the colour changes were a relevant parameter for determining the fruit ripening. Hue angle value decreased along the process because of the respiration activities.

Stages of maturity in fruits commonly walk along through the process of ripening. During these two processes, the quality of fruits and vegetables can be influenced. Biochemical changes will occur and the complex process that causes the development of the changes in the metabolism of the fruit and vegetable to occur.

Several physicochemical factors can attribute to the changes in the nutritional quality of the fruits and vegetables several contents like sugar will degrade along together with both processes, ripening and maturity stages.

(Zahoorullah, Dakshayani, Swaroopa Rani and Venkateswerlu (2017) stated that there are colour changes in the brinjal between coated and uncoated brinjals. The uncoated brinjals appear more purplish compared to the coated brinjal.

Based on Appendix A and Figure 4.1.1 after 12 days of observation, the highest hue angle was observed in control (21.20). The lowest hue angle was observed in a chitosan concentration of 2.0% (6.220). Chitosan with 2.0% concentration is more effective in slowing ripening stage of brinjals at ambient temperature.

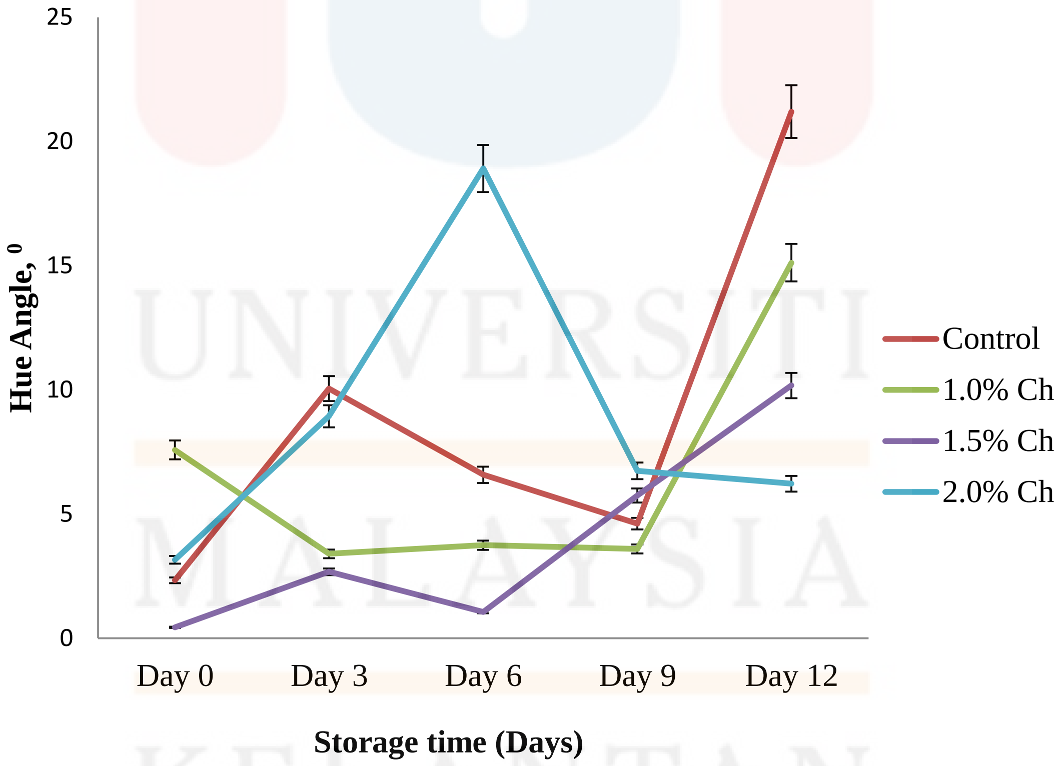

Figure 4.1.1: Hue angle changes of brinjals at ambient temperature

For cool storage, based on the Figure 4.1.2 the uncoated brinjals ripen faster than coated brinjals and the changes seemed to undergo fluctuation with rapid changes from day 6 to day 12. At day 12, the chitosan concentration of 1.0% shows the lowest hue angle while control or uncoated brinjals show the highest value of hue angle. The treated brinjals with 1.0% concentration of chitosan were the best treatment in detaining the deterioration at day 12.

Rapid spoilage is occurred because of the rate of respiration is too high. Because of the high rates of the respiration process the dehydration and metabolism process work very fast and the rate become high too. Because of the metabolism and dehydration process that works very fast caused the spoilage becomes fast. The shelf life of brinjals is short. The shelf life of the brinjals can depend on the condition during the developmental stage during harvest time and the storage conditions during post-harvest management. Moreover, due to the tropical or subtropical origin, brinjals are susceptible to chilling injury (CI) when stored at low but non-freezing temperatures Valenzuela et al. (2017). Slowing down the respiration rate is the best methods to maintain the condition and quality of the brinjals. Make sure to slow the respiration rate by managing the suitable temperature because the lower temperature can slow down then respiration rates. The common temperature is from 10 to 13 ^{0}C. The controlled atmosphere can retard chilling injury.

Valenzuela et al. (2017) stated that temperature lower than 10 ^{0}C like 8 to 9 ^{0}C can induce the chilling injury and cannot be kept for longer storage. The chitosan coating 1.0% shows that the coating can protect the brinjals from chilling injury. The ripening process of brinjals by the differentiation value of the hue angle shows that coated brinjals can lower the ripening process of the brinjals. Chilling injury can occur to brinjals because it is sensitive to the low temperature especially temperature under 10 depends on the cultivars, the origin of the brinjals, the size during harvesting, environmental conditions development stages.

Based on Appendix B and Figure 4.1.2 after 12 days of observations, the highest hue angle reading was on control (11.220). The lowest reading was on coated brinjals with 1.0% concentration of chitosan (1.10). The chitosan coating with 1.0% concentration works more effective compared to other concentration at cool storage.

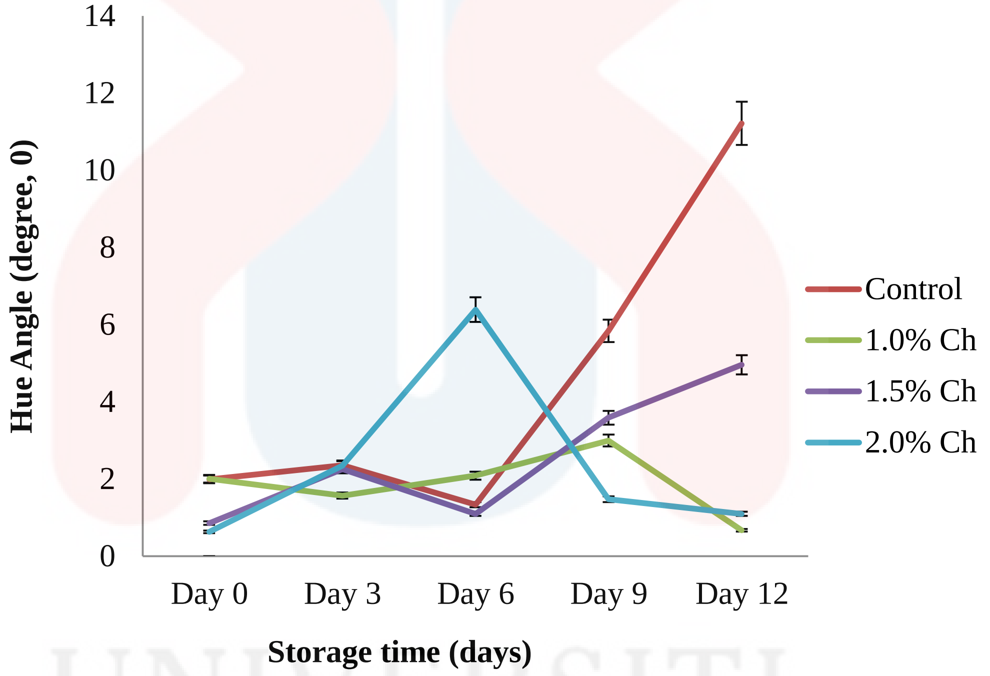

Figure 4.1.2: Hue angle changes of brinjals at cool storage

For effect of different concentration of chitosan on hue angle at different temperature the result for concentration of chitosan coating is slightly different compared the different temperature. For ambient temperature, concentration of 2.0% is better while for cool storage, the concentration of 1.0% is better. There is no significant difference between treatment and temperature storage (P>0.05) (Appendix I).

4.2 Effect of Different Concentration of Chitosan on TSS

Ethylene is the hormone produce in plant to manage the ripening process of the fruits. Ethylene hormone is very important in controlling fruit physiology especially during its postharvest conservation period or storage period. Ethylene is closely related to the ripening process that can cause the ripening of the brinjals during the storage. Common response to ethylene is related to ripening. Ripe brinjals contain higher sugar content but if over ripe the taste of the brinjals can turn sour or bitter (Valenzuela et al., 2017)

The lowest TSS value was observed on brinjals that coated with 2.0% concentration. The concentration is suitable to reduce the process of ripening from occurring very fast. The brinjals can be kept for long.

For ambient temperature, based on Appendix C and Figure 4.2.1 after 12 days, the highest TSS was observed in coated brinjal with 1.0% concentration (7.4%). The lowest was observed on coated brinjals with 2.0% concentration (6.1%). Chitosan at 2.0% was found to be more effective in delaying the total soluble contents reduction.

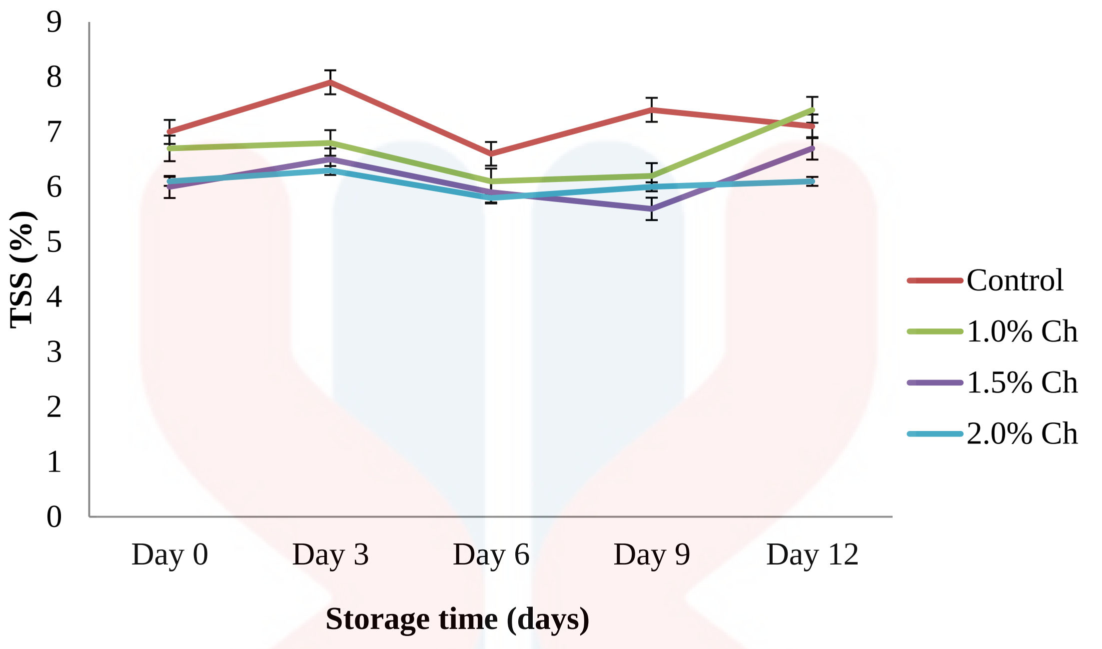

Figure 4.2.1: TSS changes of brinjals at ambient temperature

Mechanical injury occurs during handling the fruits and vegetables during harvesting process, washing, storing and also transporting. Mechanical injury caused a lot of damage to the product. Mechanical injury also can promote ethylene production. Including mechanical injury, decay, insect damage and some types of stress such as low or high temperature also can contribute to the ethylene production. The cold-induced ethylene production has also been observed on brinjals. Even after cold storage, ethylene production is dependent upon the level of sensitivity of the fruit to cold. It is always associated with an up-regulation of ethylene biosynthesis genes (Valenzuela et al., 2017).

The lowest value of TSS was on brinjals that coated with 1.0% concentration. 1.0% concentration is the best to reduce ripening process from occurring fast at the cool storage.

For cool storage, after 12 days, the highest total soluble solid was observed on brinjals that coated with 2.0% concentration of chitosan (7.1%). The lowest were observed on nrinjals that coated with 1.0% concentration (Appendix D and Figure 4.2.2).

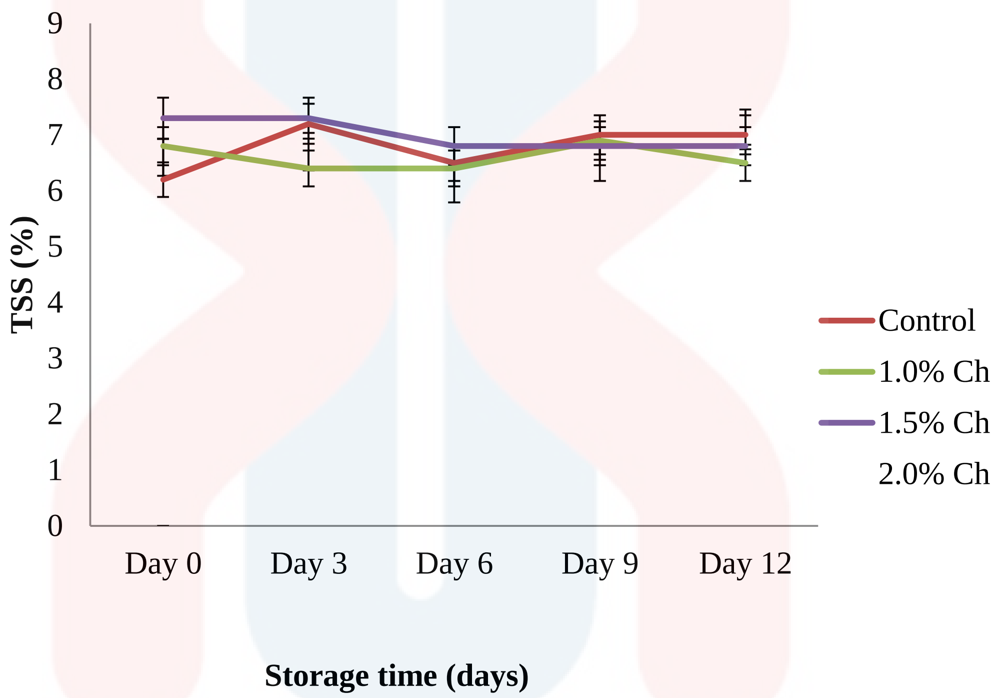

Figure 4.2.2: TSS changes of brinjals at cool storage

Effect of different concentration of chitosan on TSS at different temperature, There are different between the better chitosan concentrations on brinjals within the different storage. At ambient temperature, chitosan concentration with 2.0% performed better than other concentration and the uncoated brinjals shows the lowest reading. At cool storage, the chitosan with 1.0% concentration performed better than other concentration and the lowest is the brinjals that coated with 2.0%. There is significant difference between treatment and temperature storage (Appendix J).

4.3 Effect of Different Concentration of Chitosan on Firmness

At ambient temperature the uncoated and coated brinjals shows decreased in the value of the firmness. At the day 12, chitosan with concentration 2.0% shows the highest value of firmness compared to others. The result clearly shows that the uncoated brinjals have the lowest value of firmness at day 12 (Figure 4.3.1).

From the study of Zahoorullah, Dakshayani, Swaroopa Rani and Venkateswerlu (2017), the highest firmness loss was observed in brinjal that uncoated with chitosan. However Valenzuela et al. (2017) stated that brassinosteroids can maintain the membrane integrity and moisture and reduced flesh browning and reduced phenolic accumulation. By maintaining the membrane integrity, the firmness of the brinjals can be protected. Chitosan coating shows that it is useful to lower the decrease value of firmness towards Zucchini.

After 12 days, the highest firmness was observed in coated brinjals with 2.0% concentration (1555.83g). The lowest was observed on uncoated brinjals (1230g). The chitosan with 2.0% concentration was found to be more effective in delaying the firmness of the brinjals (Appenndix E).

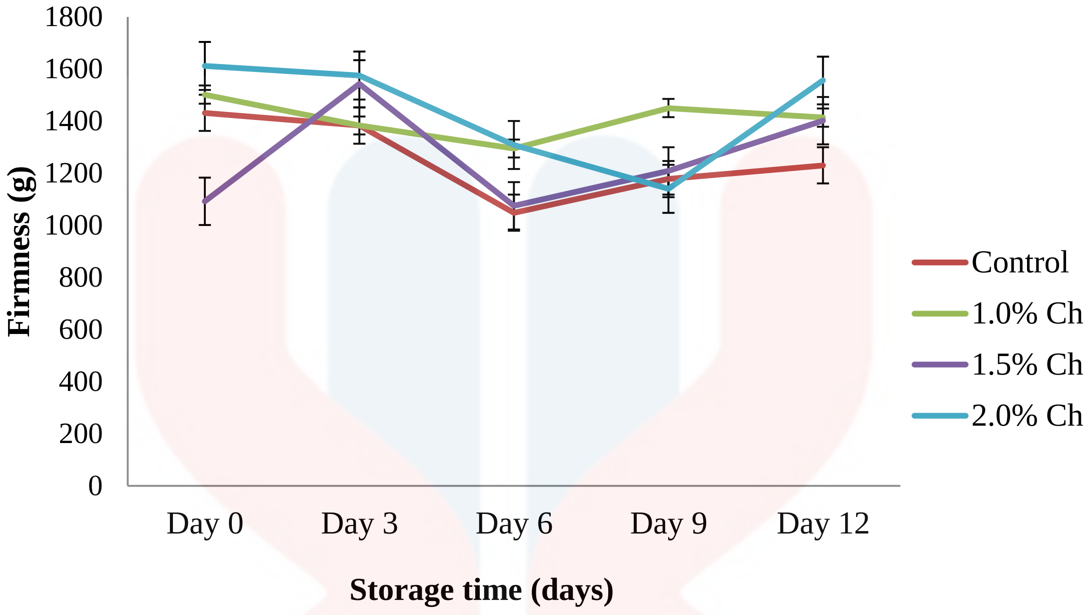

Figure 4.3.1: Firmness changes of brinjals at ambient temperature

Effect of different concentration of chitosan on firmness at cool storage based on the Figure 4.3.2 stated that the uncoated and coated brinjals shows decreased in the value of the firmness. At day 12, chitosan with concentration 1.0% shows the highest value of firmness compared to others. The result clearly shows that the uncoated brinjals have the lowest value of firmness at day 12.

Valenzuela et al. (2017) found that eggplant fruit treated with 1-methylcyclopropene (1-MCP) maintained fruit firmness concomitantly with a reduction in water loss, this probably being caused by a delay produced by 1-MCP in senescence of the calyx.

Valenzuela et al. (2017) mention that the storages of fruit under cold conditions a generalized technology used to avoid rapid decay and maintain quality. Low temperature slows down many of the processes responsible for the deterioration and loss of quality in vegetable fruits. Chitosan-based coatings were also observed to improve the shelf life of cucumbers zucchini, bell peppers, eggplants and sponge gourds.

After 12 days, the highest firmness was observed in coated brinjals with 1.0% concentration (1605g). The lowest firmness was observed on brinjals that coated with 2.0% concentration. Brinjals coated with 1.0% concentration was found to be more effective compared to other concentration (Appendix F).

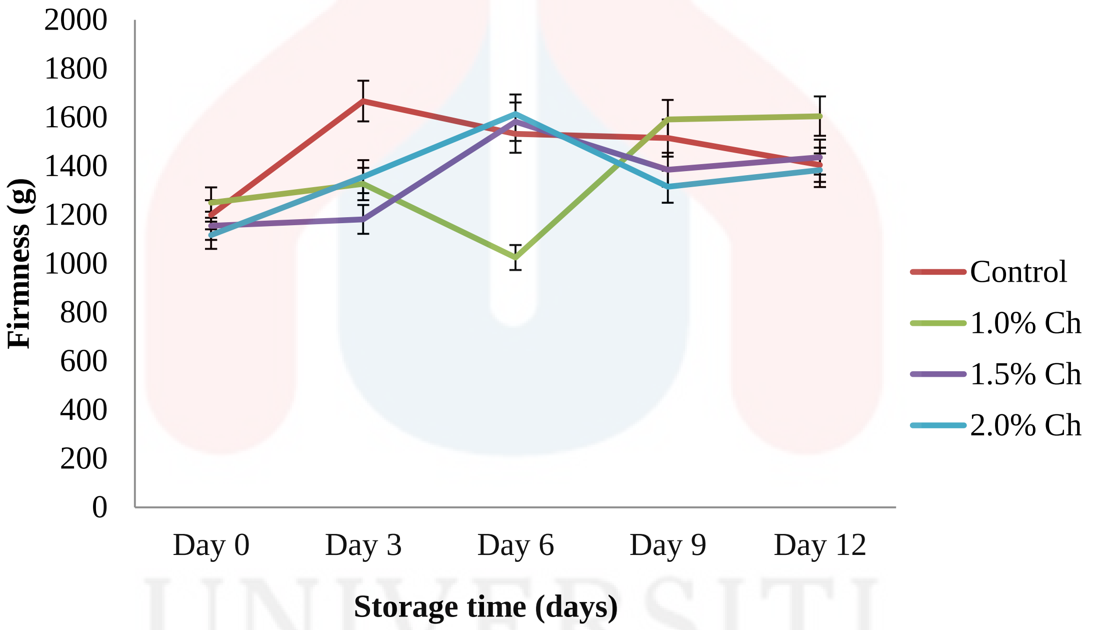

Figure 4.3.2: Firmness changes of brinjals at cool storage

Effect of different concentration of chitosan on firmness at different temperature for ambient temperature, 2.0% concentration worked the best to increase the firmness of value of the brinjals while at cool storage concentration 1.0% works the best. There is no significant difference between treatment and temperature storage ($P>0.05$) (Appendix K)

4.4 Effect of Different Concentration of Chitosan on Weight Loss

The effect of different concentration of chitosan on weight loss at ambient temperature observed that the uncoated brinjals have the highest weight loss percentage. The brinjals that coated with 2.0% concentration have the lowest weight loss percentage after 12 days (Figure 4.4.1).

Loss of mass occurs due to the transpiration and respiration process. Dehydration is also a major cause of fruit wilting and softening, and negatively affects nutritional quality. The internal of the brinjals will loss moisture content because of transpiration process because the stomata allowed water to evaporated to the air. Other parts of brinjals that support water loss process are cuticle, epidermal cell and trichoms. With these three parts of brinjals that support transpiration process the rate of water loss become higher and lead to the weight loss of the brinjals (Valenzuela et al., 2017). The partial development of the dermal system makes immature fruits highly susceptible to water loss. The first symptom associated with fruit dehydration is wilt, which finally leads to fruit softening and shrivelling. Moreover, water loss increases ethylene production and the process of ripening will increase then the brinjals become spoil very fast. The losses of the quality occur at the same time.

Zahoorullah, Dakshayani, Swaroopa Rani and Venkateswerlu (2017) found that weight loss of the brinjals is highest for the uncoated brinjals. The brinjals that coated with 2.0% concentration have the lowest weigh loss percentage after day 12. Other research also proved that 2.0% concentration is the best to prevent weight loss of the strawberries.

After 12 days, the highest weight loss was observed in control brinjals (16.01%). The lowest weight loss was observed in coated fruit with 2.0% concentration (11.14%). Chitosan with 2.0% concentration was found to be more effective in delaying the weight loss of brinjals at ambient temperature (Appendix G).

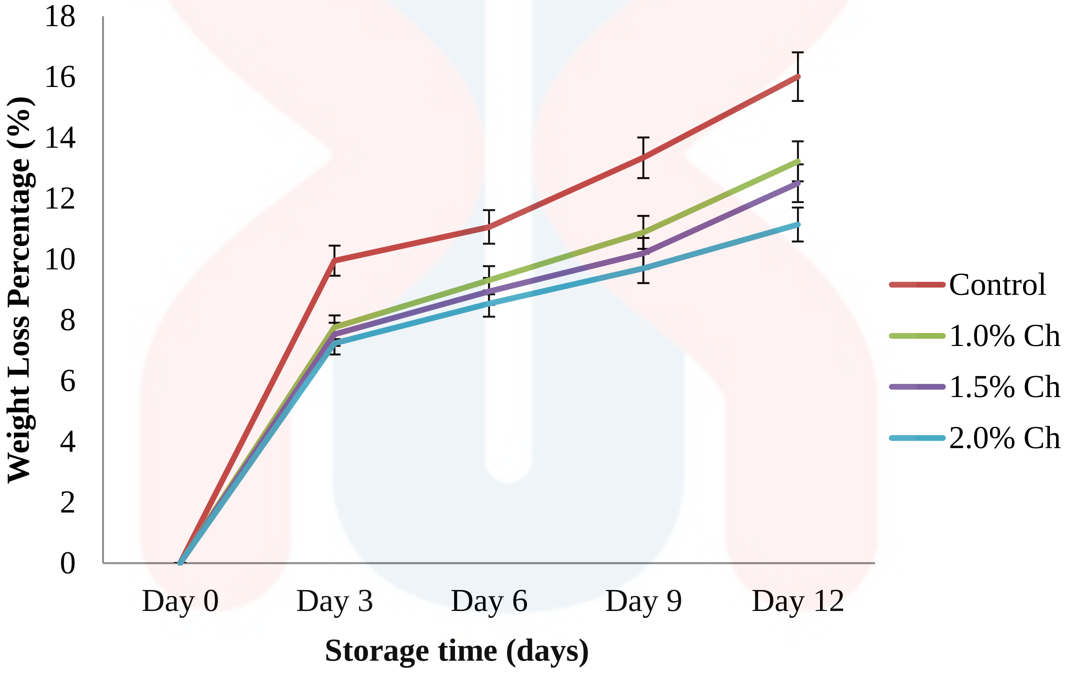

Figure 4.4.1: Weight loss changes of brinjals at ambient temperature

Effect of different concentration of chitosan on weight loss at cool storage observed that the uncoated brinjals have the highest weight loss percentage. The brinjals that coated with 2.0% concentration have the lowest weight loss percentage (Figure 4.4.2).

Valenzuela et al. (2017) stated that the brinjals that stored at low temperature can be keep for long time but only on the suitable temperature. The temperatures lower than 10^0C commonly cause damage to the quality of the brinjal. Chitosan coating can help in maintaining the cell membrane of the brinjal and reduce transpiration process that can cause water loss of the brinjal. By using the chitosan coating can reduce weight loss and chilling injury towards the brinjals.

After 12 days, the highest weight loss was observed on uncoated brinjals (9.85%). The lowest was observed in coated brinjals with 2.0% of chitosan. Chitosan with 2.0% concentration was found to be more effective in delaying the weight loss of brinjals at cool storage (Appendix H).

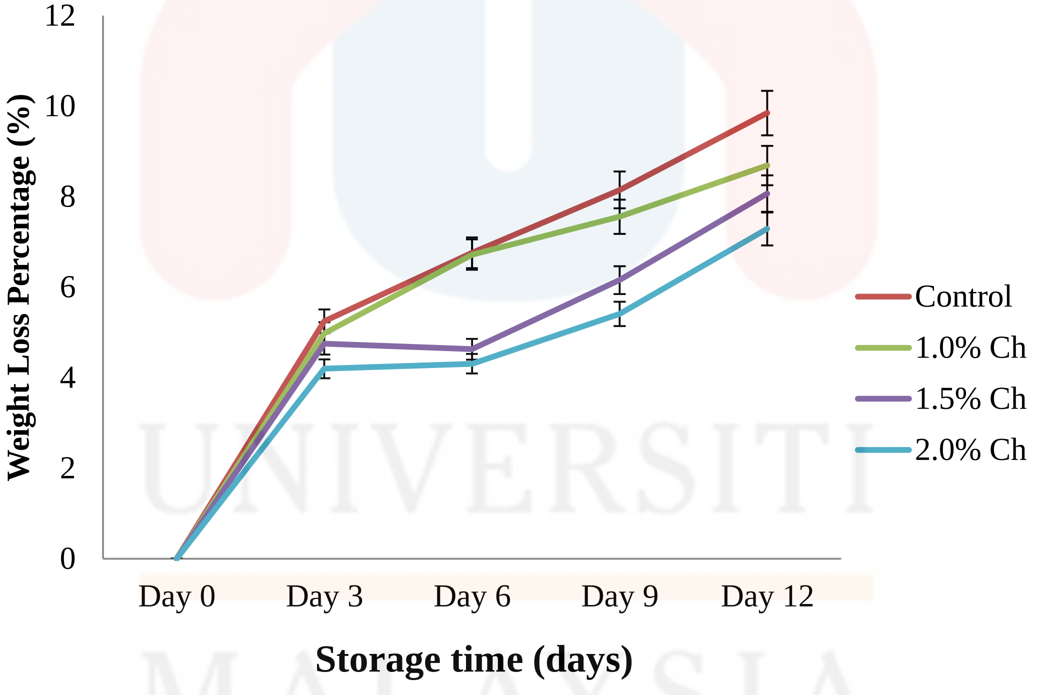

Figure 4.4.2: Weight Loss changes of brinjals at cool storage

Effect of different concentration of chitosan on weight loss at different temperature stated that both temperatures show the same result where chitosan with

2.0% concentration was found to be more effective in delaying the weight loss of brinjals. There is no significant difference between treatment and temperature storage (P>0.05)(AppendixL).

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As a conclusion, at ambient temperature, coated brinjals with chitosan is better in delaying colour changes due the ripening stage of the brinjals. The chitosan with concentration 2.0% was found as the better concentration for coating the brinjals in order to delaying colour changes. The higher the concentration of chitosan is better. At cool storage temperature, coating brinjals with concentration of 1.0% performed better than other concentration and uncoated brinjals. It helps to delaying changes of colour process for brinjals at cool storage. Chitosan with 2.0% concentration slower the reducing soluble solids in brinjals at ambient temperature while at cool storage, 1.0% concentration performed the best in reducing soluble solids in brinjals. For firmness, at ambient temperature coated brinjal with 2.0% concentration performed the best while at cool storage, 1.0% concentration shows the best result. Weight loss, both at ambient and cool storage temperatures found that 2.0% concentration performed the best in reducing the weight loss of the brinjals after 12 days of observation. Overall, at ambient temperature, 2.0% chitosan concentration performed the best at delaying colour changes, slower reduction of soluble solids content, protect the firmness of the surface and delaying the weight loss of the brinjals. For temperature at cool storage, 1.0% concentration of chitosan found that performed best at delaying colour changes, slower reduction of soluble solid contents and for protect the firmness of the brinjals. Chitosan coating was found to be suitable and effective to prolong the shelf life of the brinjals compared to uncoated brinjals. The results show that brinjals that kept in storage of cool storage temperature performed better than in ambient temperature.

5.2 Recommendation

Chitosan coating preserved the external and internal characteristics of brinjals in extending shelf life to avoid marketability. Their functions in delaying weight loss, ripening stage or colour changes, slower reduction of soluble solids contents and protect the firmness of the brinjals for at least 12 days of storage. For the future study, the study can be conducted with chitosan and other edible coating together to get the better result on prolonging the shelf life of the brinjals. The example of edible coating that can be combined together is beeswax. Use detergent like tween 20 to wash the brinjals before coating to avoid microbial activity on the brinjals. Use lower storage temperature that suitable for the brinjals and extend the due of observation to 4 weeks or one month to know how long the brinjals can be kept in good quality based on the coating and low temperature storage.

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Appendix A

Table: Mean of Hue Angle of brinjals at ambient temperature

Hue Angle (Degree, ^{0})					
Days	Day 0	Day 3	Day 6	Day 9	Day 12
Treatment					
Control	2.33	10.05	6.58	4.62	21.20
1.0% Ch	7.58	3.40	3.75	3.60	15.12
1.5% Ch	0.44	2.68	1.06	5.75	10.18
2.0% Ch	3.16	8.94	18.91	6.74	6.22

Appendix B

Table: Mean of Hue Angle of brinjals at cool storage

	Hue Angle (Degree, ^{0})				
Days	Day 0	Day 3	Day 6	Day 9	Day 12
Treatment					
Control	1.99	2.36	1.34	5.84	11.22
1.0% Ch	2.01	1.57	2.09	3.00	0.67
1.5% Ch	0.86	2.26	1.10	3.59	4.96
2.0% Ch	0.63	2.35	6.39	1.48	1.10

Appendix C

Table: Mean Total Soluble Solid (TSS) of brinjals at ambient temperature

	TSS Content (Brix, %)				
Days	Day 0	Day 3	Day 6	Day 9	Day 12
Treatment					
Control	7.0	7.9	6.6	7.4	7.1
1.0% Ch	6.7	6.8	6.1	6.2	7.4
1.5% Ch	6.0	6.5	5.9	5.6	6.7
2.0% Ch	6.1	6.3	5.8	6.0	6.1

Appendix D

Table: Mean TSS of brinjals at cool storage

	TSS Content (Brix, %)				
Days	Day 0	Day 3	Day 6	Day 9	Day 12
Treatment					
Control	6.2	7.2	6.5	7.0	7.0
1.0% Ch	6.8	6.4	6.4	6.9	6.5
1.5% Ch	7.3	7.3	6.8	6.8	6.8
2.0% Ch	6.6	6.7	6.1	6.5	7.1

Appendix E

Table: Mean of firmness of brinjals at ambient temperature

	Firmness (Force, g)				
Days	Day 0	Day 3	Day 6	Day 9	Day 12
Treatment					
Control	1431.67	1383.33	1048.33	1177.50	1230.00
1.0% Ch	1501.67	1383.33	1295.00	1450.00	1413.33
1.5% Ch	1091.67	1543.33	1075.00	1208.33	1401.67
2.0% Ch	1611.67	1575.00	1308.33	1140.00	1555.83

Appendix F

Table: Mean of firmness of brinjals at cool storage

	Firmness (Force, g)				
Days	Day 0	Day 3	Day 6	Day 9	Day 12
Treatment					
Control	1200.00	1666.70	1531.67	1515.00	1405.00
1.0% Ch	1250.00	1326.67	1025.00	1591.67	1605.00
1.5% Ch	1155.00	1181.67	1581.67	1385.00	1436.67
2.0% Ch	1116.67	1356.67	1613.33	1315.00	1383.33

Appendix G

Table: Mean of Weight Loss of brinjals at ambient temperature

	Weight Loss (%)				
Days	Day 0	Day 3	Day 6	Day 9	Day 12
Treatment					
Control	0.00	9.95	11.06	13.34	16.01
1.0% Ch	0.00	7.76	9.31	10.88	13.22
1.5% Ch	0.00	7.53	8.94	10.19	12.50
2.0% Ch	0.00	7.23	8.54	9.70	11.14

Appendix H

Table: Mean of weight loss of brinjals at cool storage

	Weight Loss (%)				
Days	Day 0	Day 3	Day 6	Day 9	Day 12
Treatment					
Control	0.00	5.25	6.76	8.15	9.85
1.0% Ch	0.00	4.98	6.72	7.56	8.69
1.5% Ch	0.00	4.75	4.63	6.16	8.07
2.0% Ch	0.00	4.20	4.31	5.41	7.29

Appendix I

Table: Two way ANOVA analysis for Hue Angle

Tests of Between-Subjects Effects

Dependent Variable: hueangle

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	283.300[a]	7	40.471	2.043	.080
Intercept	991.219	1	991.219	50.046	.000
Temperature	182.756	1	182.756	9.227	.005
Treatment	68.723	3	22.908	1.157	.341
Temperature * treatment	31.821	3	10.607	.536	.661
Error	633.794	32	19.806		
Total	1908.313	40			
Corrected Total	917.094	39			

a. R Squared = .309 (Adjusted R Squared = .158)

Appendix J

Table: Two way ANOVA analysis for TSS

Tests of Between-Subjects Effects

Dependent Variable: TSS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5.256[a]	7	.751	5.108	.001
Intercept	1756.950	1	1756.950	11952.043	.000
Temperature	.552	1	.552	3.757	.061
Treatment	2.233	3	.744	5.063	.006
Temperature * treatment	2.471	3	.824	5.603	.003
Error	4.704	32	.147		
Total	1766.910	40			
Corrected Total	9.960	39			

a. R Squared = .528 (Adjusted R Squared = .424)

Appendix K

Table: Two way ANOVA analysis for Firmness

Tests of Between-Subjects Effects

Dependent Variable: firmness

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	198871.240[a]	7	28410.177	.850	.556
Intercept	74165562.456	1	74165562.456	2217.755	.000
Temperature	16676.197	1	16676.197	.499	.485
Treatment	49024.586	3	16341.529	.489	.693
Temperature * treatment	133170.457	3	44390.152	1.327	.283
Error	1070135.389	32	33441.731		
Total	75434569.085	40			
Corrected Total	1269006.629	39			

a. R Squared = .157 (Adjusted R Squared = -.028)

Appendix L

Table: Two way ANOVA analysis for Weight Loss

Tests of Between-Subjects Effects

Dependent Variable: weightloss

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	135.219[a]	7	19.317	1.062	.410
Intercept	1823.580	1	1823.580	100.270	.000
Temperature	104.071	1	104.071	5.722	.023
Treatment	28.434	3	9.478	.521	.671
Temperature * treatment	2.715	3	.905	.050	.985
Error	581.976	32	18.187		
Total	2540.775	40			
Corrected Total	717.195	39			

a. R Squared = .189 (Adjusted R Squared = .011)

Appendix M

Figure: The brinjals after 12 days at ambient temperature

Figure: The brinjals after 12 days in cool storage