THE EFFECT [illegible] HARVESTING DATES ON SHELF LIFE OF TOMATO (Lycopersicon esculentum)

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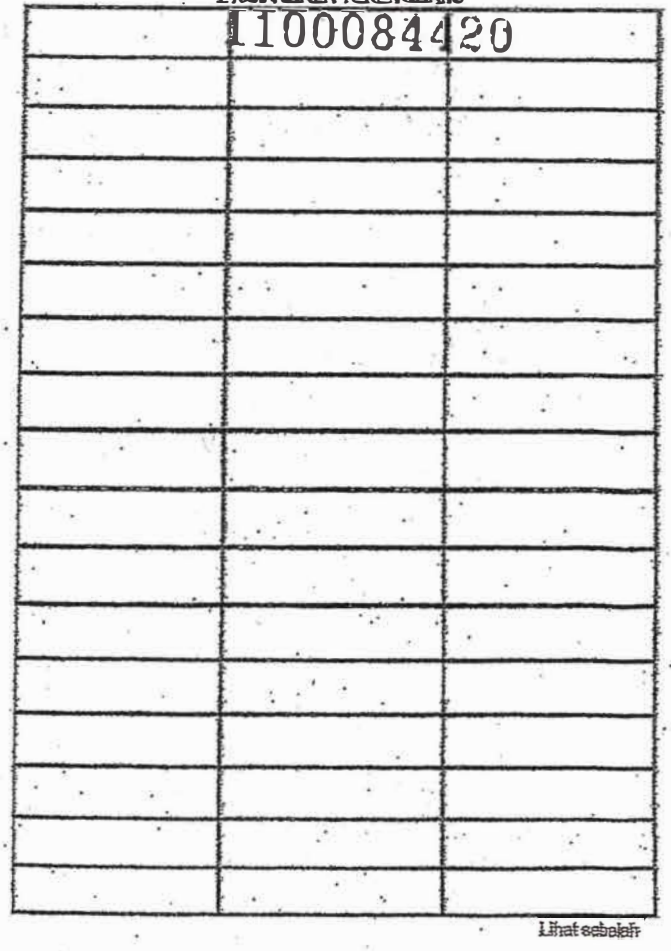
UNIVERSITI MALAYSIA TERENGGANU

2010

The effect of different harvesting dates on shelf life of tomato (Lycopersicon esculentum) / Nur Shafarina Mohd Ridzuan.



THE EFFECT OF DIFFERENT HARVESTING DATES ON SHELF LIFE OF TOMATO (*Lycopersicon esculentum*)

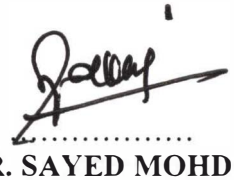
By
Nur Shafarina Binti Mohd Ridzuan

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

DEPARTMENT OF AGROTECHNOLOGY
FACULTY OF AGROTECHNOLOGY AND FOOD SCIENCE
UNIVERSITI MALAYSIA TERENGGANU
2010

ENDORSEMENT

The project report entitle The **Effect Of Different Harvesting Dates On Shelf Life of Tomato (*Lycopersicon esculentum*)** by **Nur Shafarina Binti Mohd Ridzuan** Matric No. **UK 16335** 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 (Postharvest Technology), Faculty of Agrotechnology and Food Science, Universiti Malaysia Terengganu.



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DECLARATION

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

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ACKNOWLEDGEMENTS

Thank God for blessing me in completion of my thesis. Firstly, I would like to take this opportunity to gratitude my supervisor, Assoc. Prof. Dr. Sayed Mohd Zain Bin S. Hasan for this attentive guidance, supervision and trust in me to carry out this project as an undergraduate student. His constructive comment and advices are essential in completing this thesis.

I would like to express my deepest thank to my beloved parents and all my family members for their unconditional love, concern and support since the moment I engaged with this project until I reached the finished line.

I also would like to express my appreciation to the laboratory officers and all the members for their technical assistance, cooperation and permission to use the laboratory facilities. Not forgetting to all my friends for their endless spiritual support and encouragement and always stand beside me to overcome the barriers along the way in completing this project. Last but not least, thanks to everyone that involved neither directly or not directly in contributing my project.

ABSTRACT

The effect of different harvesting dates on the shelf life of tomato (*Lycopersicon esculentum*) was investigated. The harvesting date was referred to first harvesting (one week earlier from the actual/recommended harvesting date), second harvesting (60 days after flower tagging/ recommended harvesting date) and third harvesting (one week after recommended harvesting date). After harvest, the tomatoes were analyzed and stored at ambient temperature for 9 days. The analyses parameters were measured every 3 day interval for total soluble content (TSS), vitamin C content, pH value, firmness and color changes of tomato skin. The experimental means were compared by analysis of variance (ANOVA) One-Way using SPSS 16.0 statistic software. Where differences were analyzed ($P<0.05$), use Tukey test to compare the means between 3 harvesting dates. From the results, fruits of second harvesting date had higher content of soluble solid, vitamin C and pH value compared to the first and third harvestings. However, first harvesting had higher value of firmness because the fruits were immature and the skin was firmer. While, color changes showed that the first harvesting fruits were greenish in color on day 0 and gradually changed to red over the storage at ambient temperature. Fruits of the second harvesting had lighter red skin on day 0 and gradually changed to dark red at day 9. Mean while, the third harvesting had reddish skin on day 0 and changed to brownish red at day 9. So, the best harvesting date for the best quality of tomato for storage was the second harvesting.

ABSTRAK

Kesan perbezaan waktu tuaian terhadap jangka hayat buah tomato *(Lycopersicon esculentum)* disiasat. Waktu tuaian merujuk kepada tuaian pertama (seminggu awal daripada tuaian yang disyorkan), tuaian kedua (60 hari selepas penandaan bunga/ tuaian yang disyorkan) and tuaian ketiga (seminggu selepas tuaian pertama). Selepas dituai, tomato tersebut dianalisis untuk hari pertama dan selebihnya akan disimpan pada suhu ambient untuk analisis hari ketiga, keenam dan kesembilan. Antara parameter-parameter yang diukur adalah kandungan pepejal terlarut (^{0}Brix), kandungan vitamin C, nilai pH, kekerasan buah (g) dan perubahan warna kulit buah tomato. Nilai purata yang didapati daripada eksperimen ini dibandingkan menggunakan sistem perubahan analisis, ANOVA satu jalan menggunakan SPSS 16.0 oleh perisian computer berstatistik. Apabila terdapat perbezaan ($P<0.05$), ujian Tukey digunakan untuk membandingkan purata di antara ketiga-tiga tuaian. Berdasarkan kepada keputusan yang diperoleh, buah daripada tuaian kedua mengandungi kandungan gula, vitamin C and nilai pH yang paling tinggi, walaubagaimanapun, nilai kekerasan (g) bagi tuaian pertama menunjukkan nilai tertinggi kerana buahnya masih muda dan tektur isinya masih keras. Sementara itu, perubahan warna menunjukkan bahawa buah hasil tuaian pertama adalah berwarna hijau pada hari 0 dan warnanya berubah kepada merah secara beransur-ansur semasa disimpan pada suhu ambient. Buah dari tuaian kedua mempunyai warna merah terang pada hari 0 dan secara beransur-ansur berubah kepada warna merah gelap pada hari 9. Buah yang dituai pada tuaian ketiga pula mempunyai warna merah pekat pada hari 0 dan bertukar kepada merah kecoklatan pada hari kesembilan. Jadi, waktu tuaian yang terbaik untuk mendapatkan buah yang berkualiti semasa dalam penyimpanan adalah pada tuaian kedua.

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^0C	:	Degree celcius
%	:	Percent
$NaHCO_3$	:	Sodium hydroxide carbonate
L	:	Liter
Ml	:	Mililiter
TSS	:	Total Soluble Solid
HPO3	:	Metaphosphoric acid

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CHAPTER 1

INTRODUCTION

1.1 Background study

Tomato (*Lycopersicon esculentum* Mill.) is a member of the night shade family (Solanaceae) along with the pepper, eggplant and potato. Botanically, it is classified as a fruit, since it is developed from an ovary, although it is commercially recognized and treated as vegetables.

The tomato fruit can be eaten raw, either alone or in salads and sandwiches, and it is a common ingredient in many processed and canned food products. The quality of fresh tomato fruit is a significant factor that determines its acceptability among consumers. Fruit color, shape, freedom from blemishes and pest chemical residues, and more recently from plants that have been organically grown, are factors that determine the value of the tomato fruit in the market place.

For fresh consumption, the tread has been away from beefsteak-sized tomato fruit to smaller sized (cocktail, grape, or cherry) fruit. An increasing popular marketing form is fruit-on-the-vine or what has been called "cluster tomatoes" with four or more tomato fruits still attached to the cluster vine. When looking for a more flavorful fruit, consumers frequently select the Roma type. In most of the developed world's marketplace, tomato fruit is readily available year round, the source being both field- and greenhouse-grown.

Tomato fruit should be clean and bright for best market appeal. This may require individual wiping or gentle buffing to remove water stains, dirt or dust.

Commercial tomatoes are generally sold in boxes or cartons containing 20 to 25 pounds with the tomatoes stacked only two high to reduce fruit bruising. Tomatoes are often sorted according to size and packed in similar sizes with number designations by length and width of a standard carton.

Tomatoes are now eaten freely throughout the world, and their consumption is believed to benefit the heart among other things. They contain lycopene, one of the most powerful natural antioxidants. In some studies lycopene, especially in cooked tomatoes, has been found to help prevent prostate cancer but other research contradicts this claim.

1.2 Problems Statement

As we know, the harvesting dates for fruits or vegetable usually depend on physical appearance, nutrient content or demand from marketing. However, the harvesting date will be influenced by the shelf life and quality of fruits during the storage. Early harvesting date was prolong the shelf life of fruits or vegetable but the disadvantage is the produce may be immature and the nutritional content is low.

However, late harvesting date were cause the shelf life of fruits or vegetable is short and it easily deteriorated by biological, chemical and mechanical injury. So, this study was designed to determine the best harvesting dates of tomato to prolong the shelf-life during storage with highest content of nutrient.

1.3 Significant of study

The study can help farmers to harvest the produce at the suitable time to prolong the shelf life and to make sure the produce is still fresh during transportation. This study are include the research of pre harvest factor which is influence the quantity, quality, fruits development and postharvest characteristic. The results of this study were determined through the maturity stage, final quality and the shelf life of the fruits.

1.4 Objectives

The objectives of this study are to determine the:-

1. Optimum harvesting date of tomato grown under fertigation.
2. Effect of harvesting date on the shelf life of tomato.
3. Best harvesting date that suitable to prolong the tomatoes shelf life for marketing.

CHAPTER 2

LITERATURE REVIEW

2.1 Tomato (Lycopersicum esculantum)

The tomato (*Solanum lycopersicum*, syn. *Lycopersicon lycopersicum* & *Lycopersicon esculentum*) is an herbaceous, usually sprawling plant in the Solanaceae or nightshade family, as are its close cousins potatoes, chili peppers, tobacco, eggplant and the poisonous belladonna. It is a perennial, often grown outdoors in temperate climates as an annual. (Smith, 1994)

The tomato is now grown worldwide for its edible fruits, with thousands of cultivars having been selected with varying fruit types, and for optimum growth in differing growing conditions. Tomato is said to be the native of Tropical America (Thompson and Kelly, 1957), its original home being probably in Peru or Mexico.

Tomatoes are one of our most popular vegetable crops. They are not only a mainstay of local and farmer's markets, but also a popular retail bedding plant crop. Although they are widely adapted throughout Kansas, tomatoes are a crop that requires careful management and intense labor. Crop production can be extended for several months with careful attention to fertility, pest management, crop care and timely harvest (Charles et al, 2008).

As in most sectors of agriculture, there is increasing demand in developed countries for organic tomatoes, as well as heirloom tomatoes, to make up for flavor and texture faults in commercial tomatoes. The definition of an heirloom tomato is vague, but

unlike commercial hybrids, all are self-pollinators who have bred true for 40 years or more (Smith, 1994)

.2.2 Harvesting and Handling

The harvesting process or fruits plucking is suitable to done at the first time when the plant at 90 days after it's planting or when 75 days after the plant seedling was planting in the planting hole. Another harvesting will be done at least 3-5 days until all the fruits at the tomatoes plant was finish (Bernardinus, 2007).

Harvesting should be done about 8-9 weeks after plant seedling change from nursery to the set of fertigation kids. The fruits will mature at 30 days after flowering time and the fruit production period is between 30-45 days after first harvesting. The harvesting process of greenish or yellowish green fruit will be done to avoid it from cracking. .(Department Of Agriculture, 1997)

Tomatoes are usually harvested in early morning when the field heat is not intense. Tomatoes can be harvested at various stages of ripeness. However, most Kansas markets use turning to ripe maturity stages, usually when some slight degree of color is showing on the fruit. Tomatoes are usually "precooled" immediately after harvest in refrigerated storage rooms (about 50°F). Storing at cooler temperatures may injure the fruit. Tomatoes will ripen faster at warmer temperatures, so if rapid ripening is needed, move the fruit to 70° to 80°F locations to speed up the ripening process (Charles *et al*, 1998)

Tomatoes for fresh consumption are harvested at various stages of ripeness, depending on labor costs, availability of controlled atmospheric storage facilities, distance of the production area from the market and market demands. Careful

handling the fruit to prevent bruising and injury during harvest and the subsequent sorting, grading and packing operations is very important. (Heuvelink, 2004).

2.3 Shelf-life

Shelf life is the recommendation of time that products can be stored, during which the defined quality of a specified proportion of the goods remains acceptable under expected (or specified) conditions of distribution, storage and display (Gyesley,1991). The combination of the factors such as water activity $_{aw}$, pH, redox potential, temperature and incorporation of additives in preserving fruits and vegetables is important, and all play a crucial role in improving the shelf life of fresh and processed commodities (Gustavo, 2003).

2.4 Fertigation system

Fertigation is the application of fertilizers, soil amendments, or other water soluble products through an irrigation system. Fertigation system is used nowadays for irrigation as well as for fertilizer application. Fertigation system also helps to overcome the problem of infestation of bacterial diseases. (Department of Agriculture, 1997)

Common advantages of fertigation, is the application of fertilizers through an irrigation system, include considerable savings in the labor and energy costs of application, chemicals are already in solution form and thus immediately available to the plants throughout the root zone, flexibility in irrigation timing makes it easier to schedule fertilization, soil compaction is minimized by avoiding heavy equipment

traffic through the field and small doses of chemical are applied when needed, reducing leaching of water-soluble nutrients during periods of excessive rainfall or over-irrigation (Burt *et al.* 1998, Boman and Obreza 2002).

Successful fertigation requires precise calculation of injection rates, knowledge regarding solubility of different fertilizer components, and basic know how of fertigation equipment. This publication aims to provide necessary information regarding these components. (Fares and Abbas, 2009).

2.5 Fertilizer

Tomatoes require fairly high levels of several fertilizer elements. In addition, to be productive over a period of several months, a tomato crop requires a continuous fertilizer supply. Amounts of phosphate and potash should be based on soil test results. The tomato crop requires from 75 to 150 pounds of available phosphate, which should be added prior to soil preparation in the spring and incorporated into the plant root zone. Potassium (or potash) is generally available in abundant quantities in many Kansas soils.

Addition of potassium will generally not be necessary except on very sandy soils or in soils in southeast Kansas. Nitrogen is a critical element for tomato growth and production. Many Kansas soils do not hold nitrogen in the plant root zone from season to season, so additional nitrogen is usually required. Manure or cover crops may provide some of the crop's nitrogen needs as indicated by a soil test. Approximately 30 to 40 pounds of nitrogen is usually added prior to soil preparation to provide the immediate nutrient needs of the developing crop.

Once the first fruits are marble-size, additional applications of nitrogen are side-dressed (placed along the plant row) or injected into the irrigation water (fertigation). An additional 30 to 50 pounds of nitrogen per acre is applied in side-dressed treatments or added on a more frequent basis through fertigation. Excessive applications of nitrogen in tomatoes may cause excessive vine growth and fruit quality problems. (Charles *et al*, 1998)

According to Richard (2005) statement..." If you're not familiar with the term fertigation, the process itself is simple enough. It's the application of fertilizers through an irrigation system. For more than 30 years, farmers have taken advantage of its benefits. A fertigation system is, in essence, an automatic fertilizer injection system that attaches to any in-ground sprinkler system, providing a precise amount of fertilizer over a specific period of time. The key word here is automatic".

2.6 Irrigation and drainage

In humid regions, the crop requires very less irrigation while under dry conditions it is impossible to get the crop without irrigation. In hot condition the crop should be irrigated at weekly or the days' interval whole during winter the crop should be irrigated at 15 to 20 days' interval. During fruit ripening, the interval should be increased to check fruit rotting.

Fluctuations in soil moisture from complete dry to heavy moist may cause cracking of fruits. Heavy watering is also harmful to the crop because flowers do not set properly and crop is affected by fungal disease. To avoid the situation, excess water should be drained out immediately. During rainy season, permanent drainage system should be made in the field (Singh *et al*, 2004).

2.7 Staking

Staking of the plant has proved to be very useful in the cultivation of tomato. In case of indeterminate varieties, the yield and quality of fruits is improved much more than in determinate varieties. Staking not only increases the yield and improve its quality but also reduces the infection by fungal disease. Wood sticks can be used for staking the tomato plant. Pea straw can also be used for mulching in the crop which checks the crop from touching the ground. Mulching is done about one month after transplanting (Singh *et al*, 2004).

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 Materials and methods

3.1.1 Plant materials

Seed of tomato (*Lycopersicon esculentum Mill.*) which used in this experiment was bought from the shop, supplied by Leckat Corporation Sdn Bhd under trademark 'Green World' and the seed were variety F1 hybrid 303.

3.1.2 Seedling germination

Seeds was soaked for in water 24 hours before sowed on the tray contained peat moss medium. The peat moss medium are used because it was contain fertilizer and suitable for seedling and seeds was sprayed with water for 2 time/day. The ideal temperature required is 20-25 ^{0}C and warm humid conditions improve growth. After one month, the seedling was transferred to the polybag in fertigation set.

3.1.3 Fertigation planting

Fertigation system is applied by using the compost medium such as small rock or husk of coconut. This system is so special because of applying the mineral fertilizers for the crops along with the irrigation water and without using the soil. The

fertigation system in various trickle-irrigation technologies involves the injection of fertilizer solutions into irrigation systems via calibrated injection pump.

The quantity of water with fertilizer and time for irrigation depend on the size of the plant. In this study the fertilizer use is two type, set A and set B.

Solution for set A and set B must be separate in different container for avoid chemical action. A litter solution of set A ans set B fertilizer in to the water and by using the EC Meter for make sure the quantity of fertilizer is enough before trickle down. The process of fertilizer application were conducted with timer. The trees was watered with concentration of fertilizer according to table below.

Table 3.1: The schedule of fertilizer during planting using the fertigation system

Weeks	Time (6 time/day)	Minute	EC Meter
1	7.30am, 9.30am, 11.30am, 1.30pm, 3.30pm, 5.30pm	4	1.4 -1.6
2	7.30am, 9.30am, 11.30am, 1.30pm, 3.30pm, 5.30pm	5	1.4 -1.6
3	7.30am, 9.30am, 11.30am, 1.30pm, 3.30pm, 5.30pm	5	1.6 -1.8
4	7.30am, 9.30am, 11.30am, 1.30pm, 3.30pm, 5.30pm	5	2.0 -2.2
5	7.30am, 9.30am, 11.30am, 1.30pm, 3.30pm, 5.30pm	5	2.2 -2.4
6	7.30am, 9.30am, 11.30am, 1.30pm, 3.30pm, 5.30pm	5	2.4 -2.6
7	7.30am, 9.30am, 11.30am, 1.30pm, 3.30pm, 5.30pm	5	2.4 -2.6
8 until end	7.30am, 9.30am, 11.30am,1.30pm, 3.30pm, 5.30pm	6	2.5 -2.6

3.1.4 Tagging

The process of tagging was started when the flower was open. The tomato was harvested appropriately using hand or machine. The entire sample was stored at ambient temperature (24 hour) for future more chemical and physical analysis in laboratory. Tagging process is very important to calculate the accurate date for harvest.

3.1.5 Harvesting of tomato

For this study, the harvesting date was divided into three times. The first harvesting is one week early from the actual harvesting date (recommended harvesting date). Second harvesting is the actual date of harvesting (60 days after tagging/recommended harvesting date) which is as a control, and the third harvesting is one week after second harvesting.

3.2 Chemical analysis

3.2.1 Determination of vitamin C

Chemical and reagent that used is 3% metaphosphoric acid i.e 15 gm HPO3 in + 0.4653 gm ethylendiaminetetraacetic acid disodium salt (EDTA) in 500 ml distilled water or 60 gm HPO3 + 1.8612 gm EDTA in 2 liter distilled water, 0.05 gm 2,6-dichloroindophenol + 0.042 gm NaHCO3 in 150 ml hot distilled water – let it cool and dilute to 200 ml 0.1 gm Standard ascorbic acid was weight and makeup with 3% HPO3 into 200 ml volumetric flask. Taken 5 ml of standard solution and then titrated with dye.

Methods:

Take 10 gm sample into the amber beaker, and then add with 20 ml 3% HPO3 makeup to 100 volumetric flasks with distilled water. After that, the solution will filter using filter paper. 5 ml of sample will take and add with 5 ml HPO3. Then titre with indophenol dye until the color change from white to light pink.

Formula:

Standard Ascorbic Acid

Volume of titre = x ml

X ml titre of dye =2.5 mg vitamin C (5 ml standard)

Hence 1 ml =2.5 /x mg vitamin C

Ascorbic Acid Formulation:

$$\% \text{ of ascorbic acid} = \frac{\text{mean titre} * \text{Standard Factor} * \text{Dilution } (100/5) \times 100\%}{\text{Initial Weight}}$$

3.2.2 Determination of Total Soluble Solid (°Brix)

Total soluble solid for each replicate was analyzer by using refractometer (model ATAGO RR-1). This refractometer is bases on light refraction form one medium to another medium. The tomato flesh was blended to obtain a homogenous sample to make confirmed more accurate reading will be obtained. This analysis was done to determine how much the total soluble solid in the sample.

The procedure of determination of TSS (Total Soluble Solid). Firstly, grind sample until homogemous. Then, put a drop of distilled water in at the lens for calibration. After obtain the reading, dry up the distilled water using clean tissue paper. Place sample on the lens. Take the value and clean up the lens, and repeat the same procedure until done.

3.2.3 Determination of pH

pH of tomato was determined to know the volume of acidity during analysis. Sample was blended and the juice was used to determine the pH. By using pH mater (model WTW pH 702, Wissenchaftich – tenische Werkstatten), pH value of the sample was determined. A pH meter was an electronic instrument used to measure the pH (acidity or basicity) of liquid. A typical pH meter consists of a special measuring probe (a glass electrode) connected to an electronic meter that measures and displays the pH reading.

3.3 Physical analysis

3.3.1 Determination of texture

The texture of the tomato flesh was evaluated by using Texture Analyzer (TA.XT PLUS). The probe used was 5mm DIA cylinder stainless. Texture analysis was done on the sample to determine its degree of texture flexibility of a particular sample after undergo certain preconditioning treatment for a period of time.

If the texture of a particular sample was soft, therefore it can be concluded that only small amount of force are required to penetrate the sample. If the sample is more firm, more force is required to penetrate the sample.

3.3.2 Determination of L*, a*, b* values using Chroma Colorimeter

Color for tomato was evaluated using colorimeter (Chromameter model CR-200, Minolta). To measure peel color, firstly, place the measuring head on the flesh fruit surface and take approximately 3 readings on each fruits surface and find the mean. Color measurements were recorded using L*, a* and b* scale (Hunter, 1975; Francis, 1980).

The 'L' coordinate is a measure of lightness, the 'a' scale ranges from negative values for green to positive values for red and the 'b' scale ranges from negative values for blue to positive values for yellow. The L*. a* and b* values must be converted to hue value and chroma (McGuire, 1992).

3.4 Experimental Design

Data analysis was done to determine the effect of different harvesting date. The means were compared by analysis of variance, ANOVA One-Way using SPSS 16.0 statistic software. When differences were detected ($P<0.05$), Tukey test was used to compare the means between 3 harvesting dates.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Total Soluble Solis (TSS)

The total soluble solids in tomatoes are predominantly sugar, which are important contributor of flavor. In general, the flavor of fruit becomes pronounce when the sugars content at its peak. The free sugars, representing more than 60% of the solid in tomatoes, are mainly D-glucose and D-fructose, with traces of sucrose, a ketoheptose and raffinose (Salunkhe and Kadam, 1998).

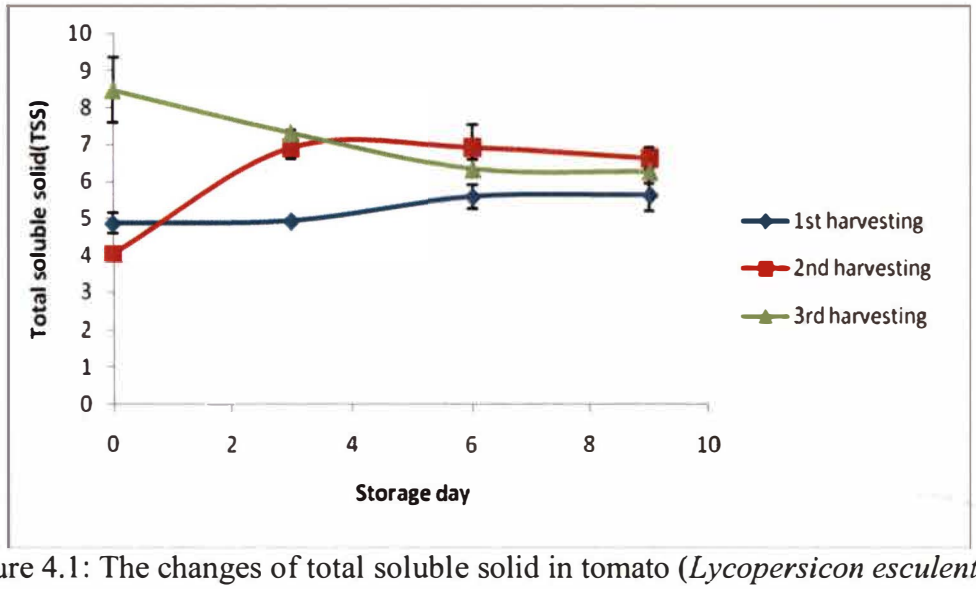

Figure 4.1: The changes of total soluble solid in tomato (*Lycopersicon esculentum*) from
different harvesting dates stored at ambient temperature 24±0.2^{0}C.

Figure 4.1 showed the value of soluble solid of tomatoes at three different harvesting dates. The value of soluble solid for three harvesting was consistent starting from day 6 until day 9. Generally, the soluble solid values for second harvesting

harvesting increased drastically from day 0 to day 3. For first harvesting, the soluble solid values were higher at day 0 but gradually decrease at day 3. While, the soluble solid values of third harvesting remained unchanged with the storage day. The result showed there is a small significant different ($P<0.05$) of soluble solid content for second and third harvesting date during 9 days stored at ambient temperature (APPENDIX A).

Changes in soluble solid contents are a natural phenomenon occurring during ripening and are correlated with hydrolytic changes in starch concentration during ripening in post harvest period. According to Kays (1997), conversion of starch to sugar in tomatoes is an important index of ripening. In addition, Tasdelen and Bayindirli (1998) also reported that total soluble solids are an important factor to be considered with respect to consumer acceptance. It is expected to increase during ripening and decrease during storage.

Total soluble solid (TSS) is one of the most important quality factors for most of fruits. Total soluble solid of 4.80-8.80% indicates the highest quality of tomato (Moneruzzaman, et al., 2008).

4.2 Vitamin C

As indicated in figure 4.2, vitamin C value for three harvesting dates showed a decreasing trend with storage time. The content of vitamin C in first harvesting was showed a fluctuation pattern with storage day. The lower value of vitamin C of first harvesting at day 0 and day 3 may be cause by poor fruits development.

The higher content of vitamin C was observed in the second harvesting and the value was gradually decreased with storage day.

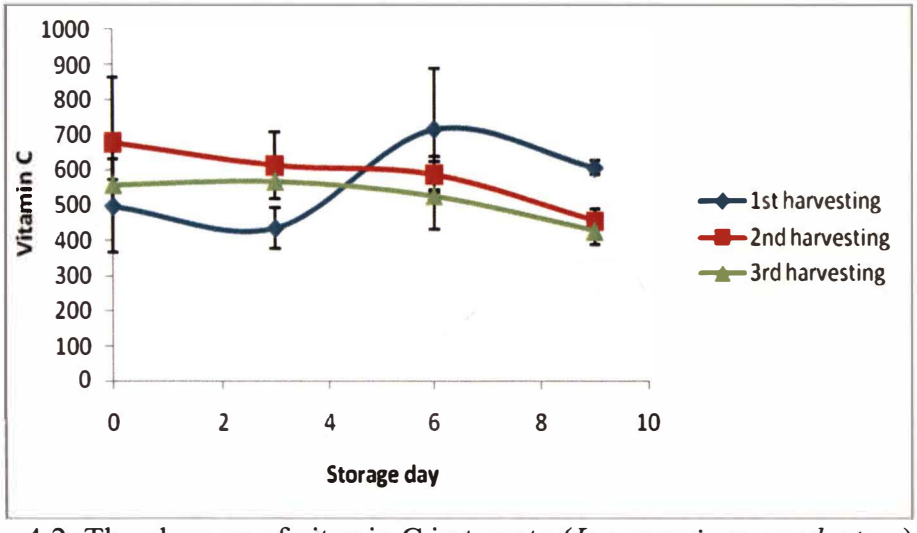

Figure 4.2: The changes of vitamin C in tomato (*Lycopersicon esculentum*) from different harvesting dates stored at ambient temperature 24±0.2^{0}C.

The result showed no significant different (P>0.05) of vitamin C content for three harvesting date during 9 days stored at ambient temperature (APPENDIX B). Vitamin C content of many fruit is higher when it is slightly immature, and declines as the fruit hits peak ripeness. Vitamin C content also decreases with storage (Romero, 1992). The vitamin C content of tomatoes increased during ripening.

There is a large variation of tomatoes in vitamin C content among tomato species and cultivar. Vitamin C ranges from 8 to 120 mg per 100 g and so there are ample genetic resources to increase the content of tomato (Kader, 1986).

4.3 Firmness (Texture)

The fruits texture plays an important role in acceptability of tomato fruits. Texture is an important attribute in evaluating the quality of tomato fruit and it is determined by the fruit morphological and physiological characteristic: epicarp firmness, amount of locule tissue and maturity stage (Sammi and Masud, 2007).

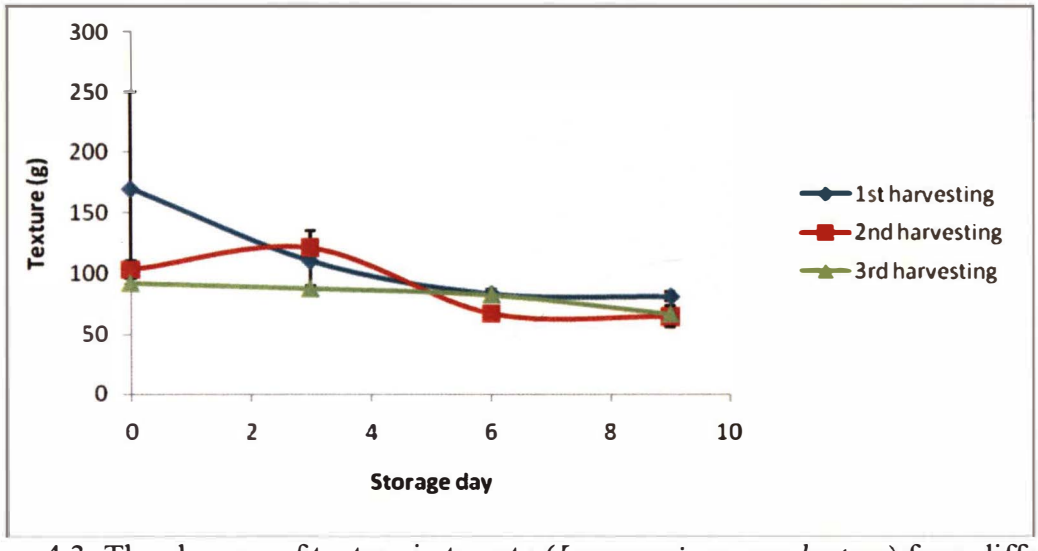

Figure 4.3: The changes of texture in tomato (*Lycopersicon esculentum*) from different harvesting dates stored at ambient temperature 24±0.2^{0}C.

According to the figure 4.3 above, firmness value showed the gradually decreasing pattern for three different harvesting dates. The higher value of firmness occurred at first harvesting, followed by second harvesting and third harvesting. The result showed no significant different (P>0.05) of vitamin C content for three harvesting date during 9 days stored at ambient temperature (APPENDIX C).

According to Batu and Thompson 1993, fruits normally soften progressively during ripening. Although exact biochemical mechanisms have not yet been fully established, it is believed that softening is largely due to the breakdown of starch and other non-pectic polysaccharides in the pulp, thereby reducing cellular rigidity (Lizada *et al.* 1990).

Softening is due in large part to breakdown of the cell wall and middle lamellae induced by pectinases (Pilnik and Voragen, 1970) and cellulases (Awad and Young, 1979), and the consequent loss of cell-wall integrity has been proposed as leading to the production of ethylene (Awad and Young,1979: Solomos and Laties, 1973).

4.4 pH value

Figure 4.4 showed a small increase of pH at day 3 but levelled off from day 6 until day 9, in all harvesting during storage. The high value of pH at day 3 might due to biological changes of tomato during storage. The result showed a significant different ($P<0.05$) of pH value for first and second harvesting while there is no significant different ($P>0.05$) of pH value for third harvesting during 9 days stored at ambient temperature (APPENDIX D). These observations are supported with finding of Khalid (1974) who found that pH value of apple juice increased during storage. This increase in pH and decrease in acidity has also been observed by Ke *et al.*, (1990) and Wright and Kader (1997).

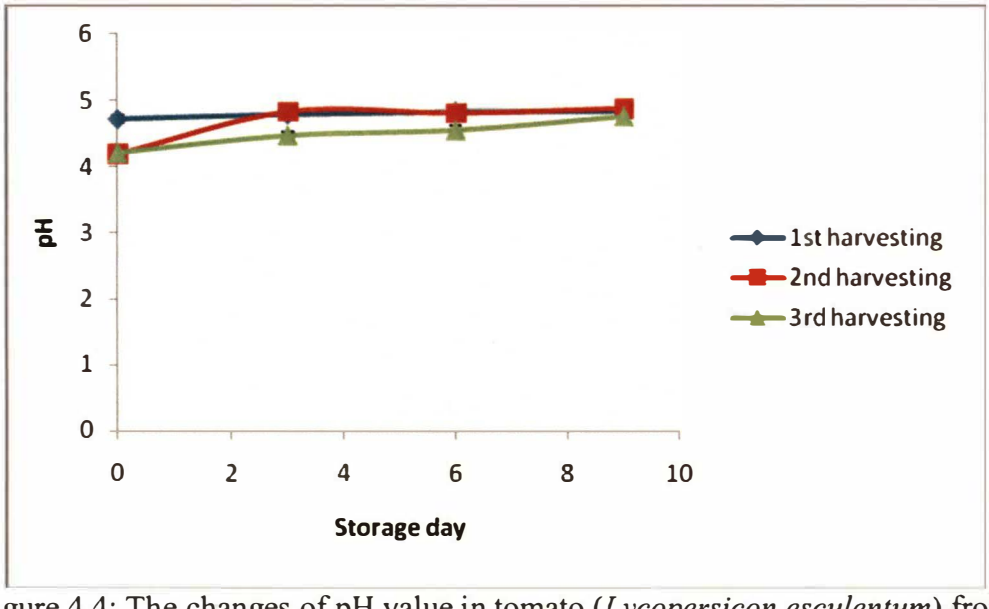

Figure 4.4: The changes of pH value in tomato (*Lycopersicon esculentum*) from different harvesting dates stored at ambient temperature 24±0.2^{0}C.

4.5 Color changes

The most obvious change in many fruits during ripening is their external color. In tomatoes chlorophyll levels are progressively broken down into phytol. It was

was observed that in tomatoes the total chlorophyll level was reduced from 5490 μg per 100 g fresh weight in green fruit to 119 μg per 100 g fresh weight in dark-red fruit (Laval-Martin *et al.* 1975). Concurrent with this degradation process, lycopene, carotenes and xanthoptylls are synthesized, giving the fruit its characteristic color, usually red (Grierson and Kader 1986). Total carotenoids in tomatoes increased from 3297 μg per 100 g weight in green fruit to 11694 μg per 100 g fresh weight in dark-red fruit (Laval-Martin *et al.* 1975). This color development occurs in both the pulp and the flesh of the tomato. The optimum temperature for color development is 240C; at 300C and above lycopene is not formed.

4.5.1 L* value

L* was the best parameter for determining the lightness of skin color. It indicates the lightness, vividness and the deeper of skin color. It appear from figure 4.5 that the L* value (lightness) of tomato showed a slightly difference between harvesting. For first and third harvesting, the L* value increased at day 3 and decreased at day 6 and day 9. While, L* value for second harvesting showed consistent trend with storage time. The result showed no significant different ($P>0.05$) of vitamin C content for three harvesting date during 9 days stored at ambient temperature (APPENDIX E).

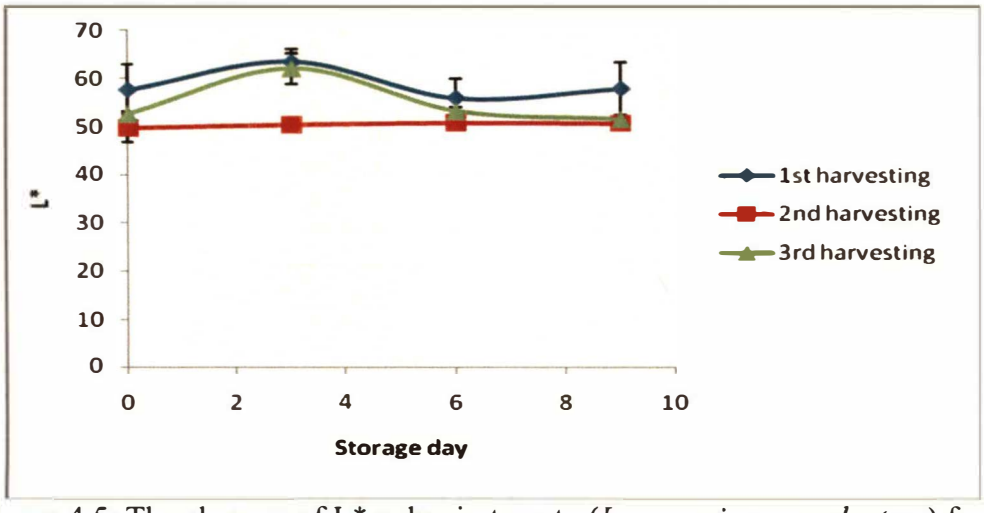

Figure 4.5: The changes of L* value in tomato (*Lycopersicon esculentum*) from different harvesting dates stored at ambient temperature 24±0.2^{0}C.

4.5.2 a* value

a* value refer to the changes from green color to red color according to Chromaticity diagram. The higher value of a* mean that the skin color of tomatoes getting more red. Figure 4.6 showed a* values of tomato skin color for three harvesting times. Fluctuation pattern was indicated between each harvesting where the a* value decreased at day 3 and drastically increased at day 6. From the result, the a* value for third harvesting was higher compared to the second and first harvesting. The result showed no significant different (P>0.05) of a* value for three harvesting date during 9 days stored at ambient temperature (APPENDIX F). As destruction of chlorophyll progresses during ripening, different shades of color such as green-yellow, yellow-orange with some trace of green, orange-yellow, orange-red and red develop in sequence (Salunkhe and Kadam 1998).

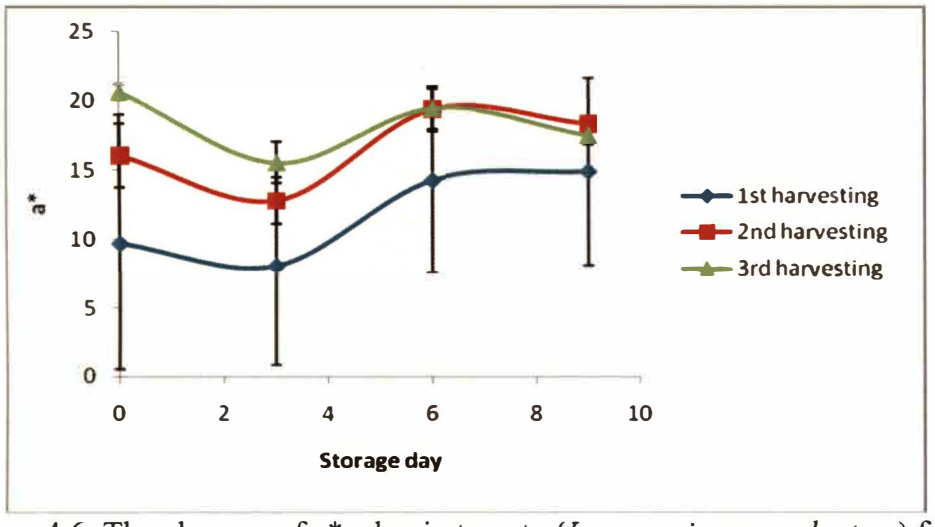

Figure 4.6: The changes of a*value in tomato (*Lycopersicon esculentum*) from different harvesting dates stored at ambient temperature 24±0.2^{0}C.

4.5.3 b* value

Positive b* value indicates the yellow color and negative b* value indicates the blue color. In all yield in all three harvesting dates, there are positive b* values which indicate the yellow color of the tomatoes. Figure 4.7 show the b* value of tomatoes skin color for three different harvesting times. According to the result, first harvesting showed the higher value of b* followed by second and third harvesting. The value of b* are decrease with storage day for each harvesting. The result showed there is a significant different (P>0.05) of b* value for first harvesting date during 9 days stored at ambient temperature (APPENDIX G).

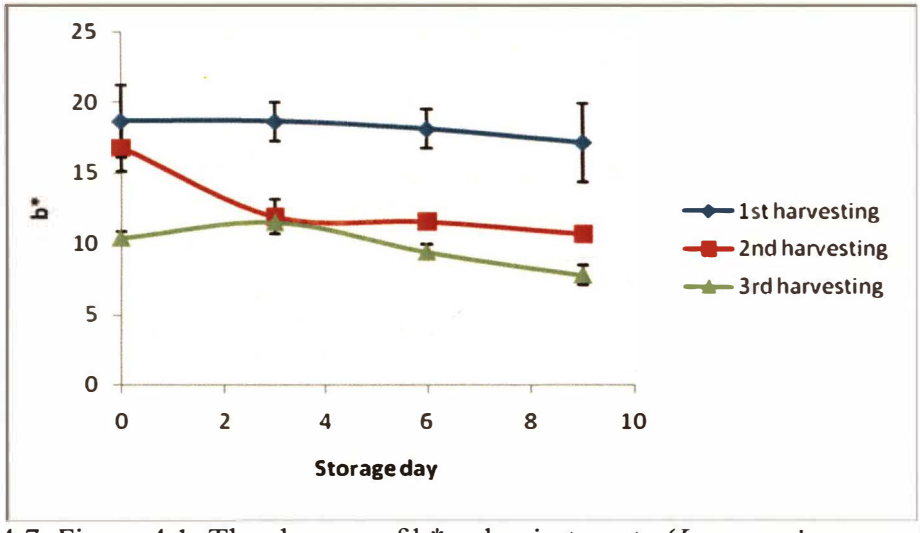

Figure 4.7: Figure 4.1: The changes of b* value in tomato (*Lycopersicon esculentum*) from different harvesting date stored at ambient temperature 24±0.2^{0}C.

CHAPTER 5

CONCLUSION

5.1 Conclusion

From the result of my study we can conclude the best quality of fruits was found when fruits was harvested at second harvesting (60 days after flower tagging). The fruits harvested at this stage will high content of total soluble solid (TSS), vitamin C and color of the fruit is shining red even it stored for 9 day at ambient temperature. However, the fruits firmness of fruits for second harvesting was lower than first harvesting.

As we know, tomato were be consume at various stage of development depends on consumer demand. For overseas imported purpose, the fruits shuld be harvested at first harvesting (53 day after flower tagging) because at this stage, the fruits physical is still green and the flesh texture is so firm.

For the fresh consumption, tomato should be harvested at second harvesting. For the usage as a tomato ketchup and tomato puree, it should be harvested at third harvesting (67 day after flower tagging) because at this stage, the physical appearance is so soft and suitable for processing.

5.2 Recommendations for further study

1. For the further study, I recomment to applied the longer storage period (extend the storage of tomatoes more than 9 days.

2. Study on the effect of storage quality (shelf life) at the optimum storage temperature of tomato

3. More parameters are done such as weight loss, pigment concentration and so on.

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APPENDIX A: Means of Total Soluble Solid (TSS) in three different harvesting date of tomato (*Lycopersicon esculentum*) during storage period at ambient temperature (24±0.2^{0}C)

Harvesting	Storage period (day)			
	0	3	6	9
1st	4.8667± 0.279424^a	4.9333±0.066667^a	5.5800±0.312143^a	5.6233±0.438799^a
2nd	4.0433± 0.080898^a	6.9167±0.305959^b	6.9100±0.624286^a	6.6200±0.288848^a
3rd	8.4667±0.866667^b	7.2667±0.077960^b	6.3333±0.240370^a	6.2467±0.326411^a

APPENDIX B: Means of vitamin C in three different harvesting date of tomato (*Lycopersicon esculentum*) during storage period at ambient temperature (24±0.2^{0}C)

Harvesting	Storage period (day)			
	0	3	6	9
1st	479.73±132.8679^a	435.1633±58.09461^a	714.6133±171.1602^a	606.2367±19.98039^b
2nd	698.785±183.1693^a	613.0077±93.43173^a	586.862±51.98868^a	454.8747±32.80765^a
3rd	558.3863±15.49628^a	568.7803±23.45633^a	526.6123±96.15063^a	425.8117±39.51296^a

Means within columns with same letters are not significantly different (P>0.05)
Means within column with different letters are significantly different (P<0.05)

APPENDIX C: Means of texture in three different harvesting date of tomato (*Lcopersicon esculentum*) during storage period at ambient temperature (24±0.2^{0}C)

Harvesting	Storage (day)			
	0	3	6	9
1st	170.2533±79.20813^a	110.63±24.41881^a	83.5000±3.951164^a	81.2333±3.705133^a
2nd	103.5767±7.029465^a	121.4533±13.42614^a	67.1033±4.719581^a	64.5933±9.075640^a
3rd	92.45667±5.894790^a	88.00667±1.816336^a	82.7267±2.725315^a	67.0667±4.942136^a

APPENDIX D: Means of pH in three different harvesting date of tomato (*Lycopersicon esculentum)* during storage period at ambient temperature (24±0.2^{0}C)

Harvesting	Storage (day)			
	0	3	6	9
1st	4.7167±0.059225^b	4.7000±0.020817^b	4.7433±0.057831^{ab}	4.8000±0.041633^a
2nd	4.1867±0.021858^a	4.8267±0.042557^b	4.8133±0.035277^b	4.8767±0.086667^a
3rd	4.2233±0.109747^a	4.4833±0.042557^a	4.5567±0.066916^a	4.7667±0.027285^a

Means within columns with same letters are not significantly different (P>0.05)
Means within column with different letters are significantly different (P<0.05)

APPENDIX E: Means of L* in three different harvesting date of tomato (*Lycopersicon esculentum*) during storage period at ambient temperature (24±0.2^{0}C)

Harvesting	Storage (day)			
	0	3	6	9
1st	57.5900±5.279176^a	63.4933±2.573171^b	55.9100±4.063992^a	57.8700±5.480003^a
2nd	49.5800±2.987245^a	50.3433±0.824001^a	50.8033±1.227930^a	50.6333±0.883937^a
3rd	52.5733±0.395488^a	62.0233±3.186562^a	53.3089±0.691191^a	51.5200±0.537773^a

APPENDIX F: Means of a* in three different harvesting date of tomato (*Lycopersicon esculentum*) during storage period at ambient temperature (24±0.2^{0}C)

Harvesting	Storage (day)			
	0	3	6	9
1st	9.6900±9.219991^a	8.0867±7.223333^a	14.2067±6.619105^a	14.7733±6.760696^a
2nd	16.0000±2.285542^a	12.7767±1.643516^a	19.3500±1.633371^a	18.3000±0.379868^a
3rd	20.5633±0.553845^a	15.4900±1.465822^a	19.4100±1.536457^a	17.4600±0.715146^a

Means within columns with same letters are not significantly different (P>0.05)
Means within column with different letters are significantly different (P<0.05)

APPENDIX G: Means of b* in three different harvesting date of tomato (*Lycopersicon esculentum*) during storage period at ambient temperature (24±0.2^{0}C)

Harvesting	Storage (day)			
	0	3	6	9
1st	18.6333±2.579783^b	18.6100±1.377546^b	18.0833±1.37583^b	17.1367±2.775826^b
2nd	16.7667±1.645138^a	11.9133±1.244378^a	11.5733±0.400056^a	10.7000±0.375411a^b
3rd	10.4100±0.485386^a	11.5333±0.51531^a	9.4233±0.547002^a	7.7900±0.692917^a

Means within columns with same letters are not significantly different (P>0.05)
Means within column with different letters are significantly different (P<0.05)

APPENDIX H: Raw data on Total Soluble Solid (TSS)

Harvesting dates	Storage period			
	Day 0	Day 3	Day 6	Day 9
1	5.00	5.00	6.07	6.47
	5.27	4.80	5.00	5.40
	4.33	5.00	5.67	5.00
2	3.93	7.40	8.13	7.13
	4.20	7.00	6.07	6.60
	4.00	6.35	6.53	6.13
3	10.0	7.13	6.00	6.27
	7.00	7.40	6.80	6.80
	8.40	7.27	6.20	5.67

APPENDIX I: Raw data on Vitamin C

Harvesting dates	Storage period			
	Day 0	Day 3	Day 6	Day 9
1	271.04	361.69	435.31	578.13
	490.99	393.95	682.86	595.69
	731.16	549.85	1025.67	644.89
2	380.62	471.99	530.60	408.20
	700.62	577.34	539.26	438.27
	1015.12	789.70	690.72	518.15
3	549.91	577.24	462.32	425.52
	536.81	524.59	401.80	494.39
	588.44	604.51	715.71	357.52

APPENDIX J: Raw data on Firmness

Harvesting dates	Storage period			
	Day 0	Day 3	Day 6	Day 9
1	84.43	63.74	85.99	74.27
	97.85	122.25	75.76	82.52
	328.48	145.90	88.75	86.91
2	91.77	146.23	76.27	50.56
	102.87	100.10	64.47	81.58
	116.09	118.03	60.57	61.64
3	85.78	90.99	77.28	75.64
	87.38	88.31	85.63	67.04
	104.21	84.72	85.27	58.52

APPENDIX K: Raw data on pH

Harvesting dates	Storage period			
	Day 0	Day 3	Day 6	Day 9
1	4.69	4.67	4.64	4.72
	4.63	4.74	4.84	4.82
	4.83	4.69	4.75	4.86
2	4.16	4.91	4.76	4.73
	4.23	4.80	4.88	5.03
	4.17	4.77	4.80	4.87
3	4.41	4.40	4.45	4.75
	4.03	4.51	4.68	4.73
	4.23	4.54	4.54	4.82

APPENDIX L: Raw data on L* value of skin color

Harvesting dates	Storage period			
	Day 0	Day 3	Day 6	Day 9
	51.38	58.39	50.71	52.40
	53.30	65.47	53.10	52.38
1	68.09	66.62	63.92	68.83
	43.83	48.71	48.38	49.03
2	51.05	51.35	51.67	52.08
	53.86	50.97	52.36	50.79
	51.89	56.07	52.15	52.48
3	52.57	66.97	52.98	51.46
	53.26	63.03	54.51	50.62

APPENDIX M: Raw data on a* value of skin color

Harvesting dates	Storage period			
	Day 0	Day 3	Day 6	Day 9
	20.06	15.31	20.65	22.13
1	17.71	15.31	21.00	20.92
	-8.70	-6.36	0.97	1.27
	18.90	11.00	22.56	18.03
2	17.61	16.06	18.27	17.82
	11.49	11.27	17.22	19.05
	21.66	13.47	19.62	18.64
3	20.15	18.34	21.96	16.17
	19.88	14.66	16.65	17.57

APPENDIX N: Raw data on b* value of skin color

Harvesting dates	Storage period			
	Day 0	Day 3	Day 6	Day 9
1	15.50	21.36	17.09	13.30
	16.65	17.09	16.36	15.58
	23.75	17.38	20.80	22.53
2	15.31	11.03	11.88	9.96
	14.94	14.37	12.06	10.96
	20.05	10.34	10.78	11.18
3	11.09	12.51	10.27	9.07
	10.67	11.33	8.40	6.69
	9.47	10.76	9.60	7.61

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THE EFFECT OF DIFFERENT HARVESTING DATES ON SHELF LIFE OF TOMATO (LYCOPERSICON ESCULENTUM) - NUR SHAFARINA BINTI MOHD RIDZUAN