



Research Article

**ANALYSIS OF THE EFFECT OF MATURITY STAGE ON THE POSTHARVEST
BIOCHEMICAL QUALITY CHARACTERISTICS OF TOMATO (*Lycopersicon esculentum* MILL.)
FRUIT**

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Abstract: Quality characteristics of tomato fruit will be affected by a number pre- and post harvest factors. In this study, the effect of maturity stage on post harvest quality characteristics of tomato was investigated. Tomato fruits of the same farmers' variety were harvested at mature-green, medium ripe and full-ripe stages. After harvesting, tomato samples were sliced and homogenized in blender for preparation of juice. The experiment was laid out using completely randomized design on juice samples. As response parameters, pH, titratable acidity, total soluble solids, sugar (total, reducing, and non-reducing sugar), and firmness were measured with three replications. Results indicated that maturity stage at harvest significantly ($p < 0.05$) affected quality attributes of tomato fruit. The highest value of pH (4.63) and TA (3.98%) was recorded in full ripe and mature green stage respectively. The increase in pH was paralleled by a decrease in titratable acidity. The highest value of total sugar (6.40%), reducing sugar (9.00%) percentage and TSS (6.57°Brix) were shown by full ripe tomatoes. As tomatoes mature, there is generally an increase in sugar content and a decrease in acidity. The pH, percentage of total sugar, reducing sugar, TSS were found to increase with advances of maturity stages at harvest. Thus, it can be concluded that the choice of fruit picking time (maturity stage) plays a key role in influencing the quality attributes of tomato fruits. Further research is recommended on more quality parameters with different types of tomato varieties.

Keywords: fruit firmness, harvesting stage, health benefit, color, post-harvest, maturity stage

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is a member of the *Solanaceae* (nightshade) family. It is an important vegetable crop grown in many countries across the world for fresh market and a multiple processed forms³¹. Tomato is the second most widely grown vegetable crop in the world other than potato Hanson *et al.*^{24,10}. Canada is the second larger producer of tomato next to Mexico, where the larger percent of this acreage is grown in the Province of Ontario^{14,15}. Tomato crop is adapted to a wide variety of climates ranging from the tropics to within a few degrees of the Arctic Circle. However, in spite of its broad adaptation, production is concentrated in few warm and rather dry areas⁴⁹. Though it is a perennial plant in tropical climates, it is grown as an annual in North America¹⁴.

Tomato is considered as an important cash generating crop for smallholders and medium-scale commercial farmers providing employment opportunity in the production and processing industries Naika *et al.*³²; Awas *et al.*⁴. Tomatoes find numerous uses in both fresh and processed forms that include ketchup, sauces, pastes and juice. Tomato is considered as an important cash generating crop for smallholders and medium-scale commercial farmers providing employment opportunity in the production and processing industries. Naika *et al.*³²; Awas *et al.*⁴ indicated that, the high nutritional value and potential health benefits of tomato have drawn an increased interest towards tomato-based products among consumers. They make significant contributions to human nutrition

throughout the world⁴⁷. Tomatoes, commonly consumed in daily diets, are a major source of antioxidants Sgherri *et al.*⁴³. Jaramillo *et al.*²⁵; Gupta *et al.*²² reported that tomatoes contribute to a well-balanced healthy diet with the right proportion of vital nutrients such as minerals, vitamins, essential amino acids, sugars, lycopene and other carotenoids and dietary fibres.

Postharvest tomato fruit quality can be affected by many factors including genetic, environmental, pre- and postharvest factors Tadesse⁴⁵. Although, cultivar (cv.) is probably the most important factor affecting the quality of fresh market and processed tomato products, maturity stage at harvest is another major factor. Maturity stage at harvest is very determinant factor for different post harvest quality attributes of tomato fruit such as soluble solid, sugar, acidity, pH colour and firmness both in fresh market and processed tomatoes. Colour and firmness are the characteristics used to determine fruit maturity and more appreciated by consumers when buying tomato²¹. Different tomato products have distinct requirements for maturity to achieve quality standards; hence, tomato maturity is one of the most important factors associated with the quality of processed tomato products. Generally, tomato maturity is divided into six stages: Green stage, breakers stage, turning stage, pink stage, light red stage and red stage based on USDA colour chart⁴⁴. The harvesting of tomato is usually implemented after the turning stage Wang *et al.*⁵⁰. Gejima *et al.*¹⁹ reported that tomato maturity is closely related to its surface color feature, so evaluating their levels of

maturity by visual analysis of the tomato's surface color features is a feasible mean.

The flavor of tomato is perceived through a combination of odour, taste, and mouth feel, and heavily relies on the balance between sugars, organic acids, volatile compounds, and free amino acids³⁵. Sweetness of tomato is mainly dependent upon the levels of total sugars; reducing sugars like glucose and nonreducing sugars like sucrose. Sucrose is mostly due to level of titratable acidity (TA) like citric acid. Sourness which is related to the level of organic acid usually masks sweetness and will be affected by maturity stage at harvest⁵. The changes of maturity stage can affect the post harvest performance and fruit quality of tomato¹⁸. Tomatoes accumulate acids, sugars and ascorbic acid during ripening on the vine^{22, 23}. In addition to chemical composition, texture is also very important quality attribute of tomato fruits.

Maturity at harvest is very important to composition and quality of tomatoes. It determines the way in which tomatoes are handled, transported and marketed and their storage life and quality³⁸. Harvesting depends up on the purpose; therefore maturity standard should correlate the quality of the fruit when ripe. Typical and advanced mature-green tomatoes will usually attain a much better flavor at the table-ripe stage than those picked at the immature or partially mature stages. Immature fruits are more subjected to shrivelling and mechanical damage, and inferior quality when ripe. Any fruit picked either too early or too late in its season is more susceptible physiological disorder and has shorter than fruit picked at proper maturity stage²⁶. The most important quality criteria for tomato are red color, firm but juice texture, good flavour⁸. Tomatoes with high sugar and relatively high acid contents are the best flavoured; low sugar and low acid contents result in poor flavoured tomatoes. Fruit texture is also very important quality attribute of tomato fruits. Fruit firmness is related to the susceptibility of tomato fruit to physical damage during harvest and storage that depends on maturity stage. Therefore, the choice of optimum fruit picking time plays a key role in having tomatoes with better quality, longer marketability and shelf life of fruits. Information regarding the effect of fruit maturity stage on postharvest quality tomato is scarce. Hence the objective of this work is to identify the optimum harvesting maturity resulting in better quality and longer marketability of ripe tomato.

MATERIALS AND METHODS

Experimental Site

This experiment was conducted in the Analytical Chemistry Laboratory, Department of Environmental Sciences, Faculty of Agriculture, Dalhousie University, Truro, Nova Scotia, Canada, between August and September, 2012. The mean minimum and maximum temperature inside the laboratory was 21°C and 22°C respectively with air relative humidity of 75%.

Plant Material and Chemical Reagents

The tomato samples representing the same farmers' variety were obtained from a local produce farm in Truro town. Representative samples were randomly taken from plot of land by excluding mottled, bruised, diseased, punctured and damaged ones for analysis of post harvest physicochemical

characteristics. The tomatoes were freshly hand harvested from the field at different maturity stages based on their surface color. After harvesting, the tomato fruit were hand washed to remove field heat, soil and also to reduce microbial populations on the surface; sorted into three classes according to their maturity stage: mature green, medium ripe and red ripe. Approximately, equal amounts fruit were used for each class of maturity stages. Tomato fruit samples were equilibrated to room condition of average temperature (21±1°C) and relative air humidity of (75%) prior to analysis. Analytical grade chemical reagents were used for the analysis of all post harvest quality characteristics of tomato fruit.

Treatments and experimental design

The treatment consisted of tomato fruit samples at different maturity stages with three levels (mature green, medium ripe, full ripe). Fruits were randomized selected from each maturity stage for the determination of firmness and skin color. The other fraction of tomato fruit from each maturity stage was used in extraction of juice for chemical analysis including pH, titratable acidity, and total soluble solid, reducing sugar, non reducing sugar and total sugar content in three replications.

Sample preparation

After equilibrating freshly harvested tomatoes fruit samples of different maturity stages to room condition of temperature and pressure, fruits from each treatment were randomly selected, washed with water and cut into pieces, then juice was extracted with fruit juicer and filtered to exclude precipitates and analyzed as per the procedure developed by official methods.

Data Collected

Physicochemical analysis

The following parameters were determined on fresh juice of all tomato fruit juice samples as response variables.

Juice content

Tomato juice was extracted from randomly selected tomato fruits of different maturity stage (mature green, medium ripe, full ripe) at harvest using a juice extractor. For measuring the juice content, a graduated glass cylinder was used and expressed in milliliter (ml) of juice per kilogram fruit weight (ml/kg) as per the method developed by Adejeji *et al.*².

pH and Titratable Acidity

The pH of the tomato juice was determined by the method described by³⁷. The fruits were chopped into small pieces, mashed by an electrical blender for 10 minutes and tomato juice was prepared using waring blender (NEW HARTFORD, CONN, USA). Then the pH meter was standardized with pH 4.0 and 7.0 buffer solutions. After standardization, 10 mL of tomato juice was added in to 50 mL beaker and then the pH of each juice sample was measured by using Microcomputer pH meter (pH-Vision, model 6071, Taiwan) with a glass electrode.

Titratable acidity of tomato juice was measured following the method developed by³⁷. The fruits were chopped into small pieces and added in to an electric blender. Five mL of Tomato juice was diluted to 95 mL of de-ionized-distilled water. The

titratable acidity of tomato juice was estimated by titrating 5 mL of the tomato juice against 0.1N NaOH solution using phenolphthalein indicator until the end point is reached. The acid content of the fruit sample was calculated based on the

volume of 0.1 N NaOH used for neutralizing the acid content in the sample and multiplying by a correction factor of 0.064 to estimate titratable acidity as percentage of citric acid. The titratable acidity was calculated using the following equation:

$$\text{Percentage of acid} = \frac{\text{mL NaOH} \times N(\text{NaOH}) \times 0.0064 \times 100}{(\text{mL juice or g Juice})}$$

Where 1ml 0.1M NaOH is equivalent to 0.0064g citric acid.

Total soluble solid (TSS)

A total soluble solid (TSS in °Brix) of the tomato juice was measured by the method described by ⁴⁶. Tomato juice was prepared by blending tomato fruit using waring blender (NEW HARTFORD, CONN, USA) for 10 minutes. Five mL of the juice was taken and centrifuged using (CL Centrifuge, AUG/78, USA) at 5000rpm. The clear supernatant (1-2 mL) was taken and filtered using a syringe fitted with a 0.45 µm pore diameter filter, and two drops of the filtrate were then carefully applied on the refractometer using plastic dropper and the reading was obtained directly as percentage soluble solids concentration (°Brix range 0 -95% at 22 °C) using bench-top scale based Abbe- refractometer (Fisher Scientific, Japan).

Determination of sugar content

A common colorimetric procedure for the analysis of the total sugar determination in fruit juice; the Anthrone method was used. The reducing sugar content was estimated by determining the volume of unknown sugar solution of tomato pulp required for complete reduction of standard Fehling's solution ¹⁶ using titration method. The non reducing sugar (sucrose) content was calculated by subtracting reducing sugar from total sugar.

Firmness

The method developed by ²⁷ was used for the measurement of fruit firmness. Texture analyzer "TA-XTPlus" (No 40555, Stable Micro Systems, Godalming, England) with flat head stainless-steel cylindrical probe of diameter 2 mm was used for the measurement of tomato fruit firmness. The start of penetration test was the contact of the probe and tomato surface and finish when the probe penetrated the tissues to depth of 8 mm with the probe speed of 1 mm s⁻¹. The point where the needle stopped was recorded as the value for the fruit firmness in kg cm⁻². Each tomato was punctured three times around the equatorial area and mean value was reported.

Data Analysis

MINITAB version 16 software package for windows by General Linear Model (GLM) was used to make analysis of variance and mean separation. All measurements were conducted in triplicates and the means were reported. Assumptions of ANOVA have been checked before analysis and they were fulfilled. The means of each response variables were subjected to analysis of variance (ANOVA), and mean separation was performed by using Tukey's student range test (t-test) at the p< 0.05 level to determine the significance if any, between the treatment means.

RESULTS AND DISCUSSION

Tomato fruits of different maturity stage were subjected to the analyses of various postharvest physicochemical quality characteristics. Important quality characteristics that determine the flavour, keeping quality and market-related quality attribute of tomato such as; pH, TA, TSS, sugar level, color and firmness were determined. Analysis of variance (ANOVA) revealed that the effect of maturity stage was significant (P<0.05) on different postharvest physicochemical quality characteristics of tomato fruits.

Juice content

The juice content of tomato fruits varied significantly (P<0.05) with advances in maturity stage. The lowest (31.66 ml kg⁻¹) and highest (38.66 ml kg⁻¹) juice content was recorded in mature green and full ripe tomato (Table 1). The difference in juice content could be due to maturity stage at harvest variation that had great contribution for the variability in fruit juice content.

Fruit firmness

The data indicated that firmness of tomato fruit was significantly (P<0.05) influenced by maturity stage at harvest. The highest value (3.20 kg/cm²) was reported in mature green tomato while the lowest value (2.20 kg/cm²) was reported in full ripe tomato (Table 1). Firmness decreased notably with advance in maturity stage of tomato fruit i.e. mature green tomato was noted to be the firmest (Table 1). Similar result was recorded by ² who reported that firmness of tomato fruit decreased with maturity stage at harvest. Fruit firmness is indicative of level of softening of the fruit that can be affected by maturity stage at harvest time. Fruit firmness is related to the susceptibility of tomato fruit to physical damage during harvest and storage. The decrease in fruit firmness with advance in maturity stage may be related to the degradation of polysaccharides.

pH and Titratable acidity

The pH value of tomato fruit varied significantly (p<0.05) in fruits of different maturity stages. The minimum (4.23) and maximum (4.63) pH values of the fruit samples were recorded in mature green and full ripe tomato fruit samples respectively (Table 1). Similar results were also reported by Borji et al. ⁵ that the pH of tomato fruit will increase with advancement in maturity stage from mature- green to full-ripe stage. The pH of tomatoes is determined primarily by the acid content of the fruit that determine the product safety. Anthon et al. ³ suggested that pH 4.4 is the maximum desirable for safety and the optimum target pH should be 4.25 to ensure food safety. ³⁴ reported that values of pH are crucial for processing tomatoes since values higher than 4.4 mean susceptibility of the pulp to

thermophilic pathogens. Thus, pH values as low as possible (up to the point that it does not adversely affect taste) should be bred into tomato cultivars for industrial use²⁰. From the present result of pH value of tomato fruits at different maturity stage during harvest, full ripe tomato may not be recommended for fresh tomato consumption and industrial processing unless and otherwise it undergoes drastic thermal treatment like low-acid foods (pH>4.6) for safety issues.

Titrateable acidity (%) content of tomato fruit ranged from 3.98 % to 2.11 % (Table 1). Acidity decreased significantly ($p<0.05$) among the maturity stages (from mature green to full ripe) in percentage of titrateable acidity. Maximum acidity (3.98 %) was found in mature green tomato, which decreased gradually with advance in maturation. Maturity at harvest had a significant effect on the acidity of tomato and the values were significantly different from each other. Analogous result was also reported by De Castro *et al.*¹³ presenting an acidity decrease with the progress of maturity. Wills *et al.*⁵¹ also mentioned that the amount of organic acids usually decreases during maturity, as organic acids are substrates of respiration. Two important quality attributes of processing tomatoes are pH and titrateable acidity (TA). From this experiment, it is noted that the increase in pH was paralleled by a decrease in titrateable acidity, due to a loss of citric acid which is the dominant acid in tomato and indicates that acid concentrations in the fruit are declining with maturity. This result is in agreement with finding of Anthon *et al.*³ who reported that tomato fruit acidity decreases during the course of maturation. Other acid found in tomato fruit in less concentrations are malic acid, and glutamic acid.

Total Soluble Solid

Total Soluble Solid (TSS) content of tomato fruit ranged from (4.47 to 6.57) °Brix in this study (Table 1). The highest value

(6.57 °Brix) of TSS was recorded in full ripe tomato fruit where as the lowest value (4.47 °Brix) was recorded in mature green tomato fruit. It was noted that, maturity stage at harvest has significantly ($P<0.05$) affected the total soluble solid content of the fruit. Similar finding was reported by⁵ in which the TSS content of mature green and full ripe tomato was 5.1 and 6.2 °Brix respectively. Anthon *et al.*³ reported that the soluble sugars glucose and fructose are the largest contributor to the total soluble solids. Soluble solids are a large fraction of the total solids in tomato and an indicator of sweetness, although sugars are not the sole soluble component it measures¹⁴. In addition, Salunkhe *et al.*⁴² reported that soluble solids content increases with fruit maturity through biosynthesis process or degradation of polysaccharides. Kumar *et al.*²⁸ reported that TSS content of tomato fruit in the range of (4.80-8.80 °Brix) indicates the highest quality of tomato fruit for industrial processing. Total soluble solid is an important quality parameter for suitability of tomato in industrial processing for production of paste. Similar finding was reported by Campos *et al.*⁷ where the minimum TSS content of 4.47 °Brix for mature green is considered low quality and the full ripe tomato with TSS content of 6.57 °Brix is considered high quality for industrial processing. Larger degree Brix values are frequently correlated with greater tomato product yield. The high value of total soluble solid increases tomato paste efficiency and this value must be between 5 and 6.5% in industrial tomatoes¹⁸. The increasing trend in TSS content could be due to a lower TSS accumulation in the earlier development stages as reported by Casierra- Posada *et al.*⁹. Based on the finding of this study, medium ripe and full ripe maturity stages are suitable for harvest to achieve optimum yield of tomato processing industries.

Table 1: Mean value of physicochemical properties of tomato fruit at different maturity stage

Treatments	Juice content (ml/kg)	Firmness kg/cm ²	pH	TA%	TSS(°Brix)
MG	31.66 ^a	3.20 ^a	4.23 ^a	3.98 ^a	4.47 ^a
MR	39.16 ^a	2.67 ^b	4.32 ^b	2.36 ^b	5.13 ^b
FR	38.66 ^b	2.20 ^c	4.63 ^c	2.11 ^c	6.57 ^c

Values are means of three replicates.

Mean values in each column followed by different letters are significantly different at $p < 0.05$

MG: Mature Green; MR: Medium Ripe; FR: Full Ripe

Total Sugar

Total sugar content of tomato varied significantly ($P<0.05$) in fruits of different maturity stages. Total sugar content of tomato fruit ranged from 6.40 to 9.00%. The highest (9.00 %) and lowest total sugar content (6.40 %) was recorded in full ripe and mature green tomatoes respectively. The result of the present study was in line the finding of Moneruzzaman *et al.*²⁹ who reported that, total sugar content increased with the advancement in maturity stage of tomato fruits. Tsuda *et al.*⁴⁸ reported that total sugar content will increase due to conversion of starch in to sugars. The sugar content is the most important characteristics of tomatoes as high sugars determine sweetness and are required for best flavor Rodica *et al.*⁴⁰. Wills *et al.*⁵¹ reported that, the increase in sugars renders the fruit much sweeter and more acceptable. The result reported by⁵⁴ for total sugar content of ripe tomato is between 1.7 and

4.7% which lower than the result recorded in this study. Depending on the data from this study, it can be suggested that full ripe tomato at harvest can be a good choice of harvesting stage for best flavor and aroma.

Reducing sugar content

Table 2 shows the changes in reducing sugar (RS) content of tomato harvested at different maturity stages. The reducing sugar content was observed to be significantly affected ($P<0.05$) by tomato fruit maturity stages. The reducing sugar (RS) content ranged from 2.23% to 6.33% for mature green and full ripe tomato fruit respectively. Full ripe tomato contained the highest quantity (6.33%) of reducing sugar while the mature green tomato contained the lowest quantity (2.23%) of reducing sugar content (Table 2). It estimated that reducing sugar content was increased with the progress of maturity

stage in tomato fruits. The result in this study is in agreement with the finding of Dalai et al. ¹¹; Moneruzzaman et al. ²⁹ who reported that, the reducing sugar content increased with advancement in maturity stage. Davies and Hobson ¹² showed that the sweet taste of tomato was attributed to reducing sugars. Significant differences in the reducing sugar content at different maturity stage might indicate the difference in glucose and fructose contents of tomato fruit. Thus, it can be summarized that, tomato harvested at full ripe stage contained the highest content glucose and fructose which can be recommended as good choice for tomato products processing in food industries.

Non reducing sugar

The non-reducing sugar contents varied between 2.67 to 4.17 % (Table 2). Significant difference ($p < 0.05$) among different maturity stages of tomato fruits were recorded in non-reducing sugar content. The lowest (2.67 %) and highest (4.17 %) reducing sugar content of tomato fruit was recorded in mature green and full ripe tomato respectively (Table 2). Winsor et al. ⁵³ reported that, non-reducing sugar content increased from mature green to full ripe stage in tomato fruit and this is might be due to the breaking down of starch in to sucrose and other sugars. Similar result was reported by Pinto et al. ³⁶ who reported that decrease in starch content accompanied by an increase in soluble solids, total sugar and sucrose is typical of postharvest change in climacteric fruit such as tomato.

Table-2: Mean value of juice and sugar content of tomato fruit harvested at different maturity

Treatment	Total Sugar (%)	Reducing sugar (%)	Non reducing sugar (%)
MG	6.40 ^a	2.23 ^c	4.17 ^a
MR	8.97 ^b	5.30 ^b	3.67 ^b
FR	9.00 ^c	6.33 ^a	2.67 ^c

Values are means of three replicates.

Mean values in each column followed by different letters are significantly different at $p < 0.05$

MG: Mature Green; MR: Medium Ripe; FR: Full Ripe

CONCLUSION

Tomato is an important crop in terms of its economic and nutritional value. Maturity stage at harvest is one of the most important factors associated with the post harvest quality of tomato for fresh market and different processed tomato products. In this study, it was observed that titratable acidity of tomato at different maturity stages inversely associated with pH and total soluble solid ensures good tomato fruit quality for consumer requirements i.e. a decline in TA values and an increase in TSS content as maturity stages advanced. Fruit acidity tends to decrease with maturation and a corresponding increase in sugar content of tomato fruit analyzed. The most suitable stage for long distance marketing was mature green tomato and for fresh consumption and industrial process is full ripen. In general, different stages of maturity are a determinant of tomato fruit; thereby it can directly affect changes of the fruit quality, particularly the chemical quality characteristics, color and firmness. Moreover, it can be recommended that, tomato fruits can be harvested at mature green for long distance marketing and full ripen stage for fresh consumption

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