

## Effect of Stages of Maturity and Ripening Conditions on the Biochemical Characteristics of Tomato

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**Abstract:** An experiment was carried out to evaluate the biochemical characteristics of tomato in different maturity stages and ripening conditions. Tomato (*Lycopersicon esculentum* Mill) fruits (cv. Ruma VF) were harvested at the three maturity stages viz., mature green, half ripen and full ripen and stored at three condition control (without covering), straw covering and CaC<sub>2</sub> + straw covering. At that time ascorbic acid, pH, titrable acidity, sugar (reducing, non-reducing sugar and total) percentage, TSS and acidity ratio were measured at every three days interval during storage. The highest value of reducing sugar percentage total sugar percentage and TSS percentage were shown by full ripe tomatoes, non-reducing sugar percentage, TSS and acidity ratio by mature green tomatoes and vitamin-C and titrable acidity by half ripe tomatoes at final day observation (15 or 12 days of storage). The percentage of total sugar, reducing sugar, titrable acidity, pH, TSS, TSS and acidity ratio were found to increase with gradual advancement of time, irrespective of maturity stages while percentage of vitamin-C and non reducing sugar were found to decrease with progressing time of storage. The highest values of titrable acidity were recorded in tomatoes of uncovered treatment and reducing sugar non reducing sugar, total sugar, and TSS was recorded by CaC<sub>2</sub> + straw covering treatment and vitamin C, pH, TSS and acidity ratio by simple straw covering treatment at final day of observation. The value of all the above parameters except vitamin-C and non reducing sugar were found to increase gradually with the advancement of ripening process irrespective of different keeping conditions. The tomato was placed over CaC<sub>2</sub> and covering with straw gave highest titrable acidity, reducing sugar and non-reducing sugar.

**Key words:** Maturity stage, ripening condition, physical character and tomato

### INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) fruits are often harvested at the mature green stage to minimize the damage during post-harvest handling. The fruits may later ripen spontaneously or after treatment with ethylene before shipment to retailers<sup>[10]</sup>. Losses often occurred from excessive deterioration during holding and marketing of tomatoes. This problem is especially acute with tomatoes harvested when at the breaker or more advanced stages of ripeness.

Although ripening makes fruit edible and flavorful, it also initiates the gradual deterioration of fruit quality especially in climacteric fruits such as tomato, in which the onset of ripening is considered to be initiated by endogenous ethylene<sup>[8]</sup>.

The acid content is lower in immature fruit and is highest at the stage when color start to appear, with a rapid decrease when the fruit ripens. Ripening conditions (different temperature and RH) affect the ascorbic acid content of tomato. In storage condition acid concentration decreased linearly with the increase of temperature and concentration was higher when fruit stored at 15°C<sup>[7]</sup>. pH is an importing factor in fruit processing industry. Cultivars with high pH are not suitable for processing.<sup>[16]</sup> reported a wide range of variation of pH content from 3.6-4.6 in different tomato varieties.<sup>[2]</sup> observed that ripe pineapple fruits held at 5°C had a higher pH than that held at 25°C.

Boe, *et al.*<sup>[3]</sup> observed that the acid content was found to be lower in immature fruit and it was highest at the stages when color appeared with a rapid decrease as the fruit ripened at ambient condition. They also reported that citric acid was the major constituent of total acid and malic acid occurred in small

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concentration and decrease at the fruit ripened.<sup>[19]</sup> found that maximum acidity is at the pink stage of tomato fruits with subsequent fall.<sup>[17]</sup> found that sugar content varied from 3.9-4.4% in the tomato variety.<sup>[14]</sup> reported that sugar content increased during maturation from the green mature to the red ripen stage. Sugar content varied with the stage of harvesting.<sup>[5]</sup> found that reducing sugar (%) were about 2.4% (large green), 2.90% (breaker), 3.10% (pink), 3.45% (red) and 3.65% (red ripen) of fresh weight. At all temperatures, fruits soluble sugars concentration increased with storage duration. Fruit stored at 25 or 30°C had high respiration and no marked respiratory climacteric and slow ripening. Fruits stored at 15°C had higher total soluble solids and soluble sugars but shows red color formation<sup>[7]</sup>. During maturation and ripening of fruit there are changes in total soluble solid. The total soluble solid increase from mature green stage to red ripe stage<sup>[19]</sup>.<sup>[7]</sup> reported that 4.80-8.80% total soluble solid in tomato juice. It was reported that tomato were harvested at the green mature and breaker stages and then stored 4 and 0°C. It was found that fruit soluble solids increased somewhat during storage<sup>[20]</sup>. The palatability of fruits depends on TSS and acidity ratio. Das and Akamine<sup>[1]</sup> reported that the TSS and acidity ratio of pineapple fruit increased gradually during the storage time. The total soluble solids and reducing sugar increase through out the development of fruit<sup>[3]</sup>. The fruit which are harvested green or half ripen stage were placed by the growers under different ripening conditions for rapid color development and ripening.

The fruit which are harvested green or half ripen stage were placed by the growers under different conditions for rapid color development and ripening. Due to highly perishable in nature, tomato fruit undergo serious losses at this stage. A predicted that estimation that total losses in the developing countries could be nearly 30-40% of crop harvested and the losses occur through spoilage<sup>[4]</sup>. Apart from physical losses in quality, serious losses also occur in the essential nutrients, vitamins and minerals. Improper stage of maturity, ripening conditions and lack of proper storage facilities cause a glut during the peak period of harvest and a large portion of fruits is sold at thrown away prices. The need to reduce post harvest losses is there fore a paramount important. Suitable stages of fruit maturity and optimum ripening conditions for quality and longer storage of tomato has not yet been developed for developing countries like Bangladesh. Keeping all above facts in mind, the following objectives have been included in the research project- (1) to find the suitable stage of fruit maturity. (2) to find the optimum ripening condition. (3) to asses the quality

of fruit at different stages of maturity and different ripening condition.

## MATERIALS AND METHODS

**Site:** The experimental site was in the field laboratory, Departments of Horticulture and Biochemistry, Bangladesh Agricultural University, Mymensing, Bangladesh.

**Plant material:** Freshly harvested tomato fruits (mature green, half ripe and full ripen) were selected for experiment. Three replications of 1kg fruits were placed followed by RCBD design into 3 conditions (control, straw covering and CaC<sub>2</sub>+ straw covering that's exposed to 30±1°C and 75% relative humidity. The data were analyzed by F-test and LSD test at 15 AND 5% level of probability<sup>[6]</sup>.

**Parameter study:** Ascorbic acid content of tomato pulp, pH of tomato juice, Total titrable acidity content, Sugar content, TSS content and TSS and acidity ratio of tomato pulp.

**Ascorbic acid content of tomato pulp:** Ascorbic acid in tomato pulp was estimated by 2,6-Dichlorophenol-indophenol visual titration method as described by<sup>[11]</sup>. The reagents used for the estimation of vitamin-C were as follows: 1) Metaphosphoric acid (6%) 2) Standard ascorbic acid solution 3) 2-6 dichlorophenol indophenol dye. For estimation of vitamin c, the following steps were followed: - Standardization of dye solution, preparation of solution and titration

Ascorbic acid content (mg per 100g of fruit pulp)

$$= \frac{T \times D \times V \times 100}{V_2 \times W}$$

Where,

T = Titre,

D = Dye factor,

V<sub>1</sub> = Volume made up,

V<sub>2</sub> = Volume of extract taken for estimation

W = Weight of sample taken for estimation.

**pH of tomato juice:** The pH of the sample was determine by the method described by<sup>[11]</sup>. One gram of sample was homogenized in 1 ml of boiled distilled water and 1 ml of de-ionized water of pH 7.0 and the pH of tomato juice recorded by using an electronic pH

meter. The pH meter was standardized with the help of buffer solution.

**Total titrable acidity content of tomato pulp:** Total titrable acidity was determined using the following step. At first sample blended,

Filtered, transfer to volumetric flask and volume up to mark. Titrated with 0.1N NaOH. Percentage of titrable acidity was calculated using the following formula:

$$= \frac{T \times N \times T \times V_1 \times 100}{W \times V_2}$$

Where,

T = Titre,

N = Normality of NaOH,

V<sub>1</sub> = Volume made up,

E = Equivalent weight of acid,

V<sub>2</sub> = Volume of sample taken for estimation

W = Weight of sample

**Sugar content of tomato pulp:** Sugar content was estimated by determining the volume of unknown sugar solution of tomato pulp required for complete reduction of standard Fehling's solution. The following procedure was followed in determining sugar:

- Standardization of Fehling's solution
- Preparation of sample
- Titration of reducing sugar
- Percentage of reducing sugar was calculated according to the following formula:

% reducing sugar content of tomato fruit

$$= \frac{FD \times 10}{TW \times 1000}$$

- Titration of total invert sugar
- Estimation of non-reducing sugar  
%Non-reducing sugar = % total invert sugar - %reducing sugar
- Estimation of total sugar  
% total sugar = % reducing sugar + % non-reducing sugar

**TSS content of tomato pulp:** The Total Soluble Solid (TSS) content of tomato fruit pulp was determined by using an Abbe refractometer by placing a drop of pulp solution on its prism. The percentage of TSS was obtained from direct reading of the refractometer. Temperature correction was made by using methods described by<sup>[11]</sup>.

**TSS and acidity ratio of tomato pulp:** The TSS and acidity ratio of fruit pulp was calculated using the following formula:

TSS and acidity ratio of fruit pulp

$$= \frac{\% \text{ TSS content of fruit}}{\% \text{ Acidity in fruit}}$$

## RESULTS

**Ascorbic acid content of tomato pulp:** Ascorbic acid of tomato pulp varied significantly in fruit of different maturity (Table 1). Results showed that ascorbic acid content was decreased with the advancement of ripening of tomato fruits. It was found that half ripen tomato contained the highest quantity of ascorbic acid (20.05 mg/100g tomato pulp) while the mature green tomato contained the lowest quantity of ascorbic acid (8.58mg tomato pulp) at harvest. Half ripen fruit had a sharp decrease in ascorbic acid with the advancement of storage time.

Table1: Main effect of stages of maturity on the Vitamin-C, pH and percent titrable acidity content of tomato at different days of storage

Treatment	Days of storage														
	Vitamin-C (mg 100 g <sup>-1</sup> )					pH					Titrable acidity (%)				
	0	3	6	9	12	0	3	6	9	12	0	3	6	9	12
Mature green	8.580	7.670	6.820	5.190	4.860	20.050	17.510	16.510	15.140	4.160	13.540	11.360	10.290	9.350	7.860
Half ripen	0.045	0.071	0.032	0.032	0.055	0.062	0.097	0.044	0.044	0.075	4.230	4.270	4.380	4.350	4.630
Full ripen	4.160	4.200	4.250	4.270	4.370	4.170	4.230	4.250	4.170	4.270	0.030	0.000	0.001	0.070	0.045
LSD (0.05%)	0.044	0.000	0.014	0.107	0.062	0.400	0.450	0.440	0.450	0.440	0.410	0.440	0.460	0.480	0.460
LSD (0.01)	0.420	0.450	0.450	0.460	0.450	0.001	0.001	0.001	0.001	0.001	0.014	0.014	0.014	0.014	0.014

Table2: Main effect of ripening conditions on the vitamin-C, pH and percent titrable acidity content of tomato at different days of storage

Treatment	Days of storage														
	Vitamin-C (mg 100 g <sup>-1</sup> )					pH					Titrable acidity				
	0	3	6	9	12	0	3	6	9	12	0	3	6	9	12
Uncovered	14.06	12.18	11.29	9.89	8.29	4.120	4.22	4.270	4.30	4.44	4.120	4.22	4.270	4.30	4.440
Covering (straw)	14.04	12.20	11.20	9.90	8.33	4.140	4.21	4.290	4.25	4.45	4.140	4.21	4.290	4.25	4.450
CaC <sub>2</sub> +S.covering	14.08	12.17	11.21	9.89	8.32	4.210	4.28	4.310	4.24	4.39	4.210	4.28	4.310	4.24	4.390
LSD (0.05%)	--	--	--	--	--	0.044	--	0.001	--	0.045	0.032	--	0.001	--	0.045
LSD (0.01%)	--	--	--	--	--	0.044	--	0.014	--	--	0.044	--	0.014	--	--

Table 3: Combined effects of stages of maturity and ripening conditions on the Vitamin-C, pH and percent titrable acidity content of tomato at different days of storage

Treatment Combinations	Days of storage														
	Vitamin-C (mg 100 g <sup>-1</sup> )					pH					Titrable acidity				
	0	3	6	9	12	0	3	6	9	12	0	3	6	9	12
M <sub>1</sub> T <sub>1</sub>	8.550	7.680	6.840	5.190	4.770	4.270	4.280	4.320	4.360	4.670	0.401	0.434	0.436	0.453	0.443
M <sub>1</sub> T <sub>2</sub>	8.580	7.690	6.800	5.200	4.890	4.120	4.270	4.400	4.330	4.710	0.401	0.457	0.440	0.454	0.443
M <sub>1</sub> T <sub>3</sub>	8.620	7.660	6.810	5.190	4.920	4.300	4.260	4.420	4.350	4.52	0.402	0.458	0.448	0.454	0.443
M <sub>2</sub> T <sub>1</sub>	20.030	17.540	16.540	15.140	12.220	4.200	4.170	4.250	4.290	4.380	0.402	0.440	0.470	0.479	0.443
M <sub>2</sub> T <sub>2</sub>	20.050	17.470	16.490	15.140	12.230	4.150	4.160	4.240	4.290	4.370	0.417	0.444	0.461	0.482	0.462
M <sub>2</sub> T <sub>3</sub>	20.070	17.520	16.500	15.140	12.180	4.134	4.270	4.250	4.240	4.370	0.418	0.442	0.467	0.483	0.464
M <sub>3</sub> T <sub>1</sub>	13.590	11.330	10.290	9.350	7.860	4.170	4.200	4.240	4.250	4.260	0.438	0.457	0.457	0.466	0.459
M <sub>3</sub> T <sub>2</sub>	13.480	11.430	10.290	9.350	7.860	4.160	4.200	4.250	4.130	4.280	0.431	0.452	0.460	0.470	0.455
M <sub>3</sub> T <sub>3</sub>	13.540	11.330	10.300	9.350	7.870	4.190	4.300	4.250	4.120	4.270	0.417	0.457	0.455	0.462	0.457
LSD (0.05)	0.077	0.122	0.077	0.077	0.095	0.055	0.110	0.017	0.134	0.077	0.017	0.017	0.017	0.017	0.017
LSD (0.01)	0.107	0.169	0.107	0.107	0.107	0.107	-	0.024	0.185	0.107	0.023	0.024	0.024	0.024	---
CV (%)	0.310	0.590	0.240	0.280	0.600	0.710	1.560	0.360	1.770	1.060	3.020	0.390	0.530	0.530	0.340

At 12th day of storage, the ascorbic acid contents were 12.21 mg per 100g tomato pulp and 4.86 mg per 100g tomato pulp in half ripen and mature green tomatoes respectively. The ascorbic acid content of tomato pulp did not varied significantly due to different ripening conditions irrespective of maturity stages (Table 2). It was found to decrease in case of all storage condition with the advancement of ripening process. Ripening conditions, stages of maturity and their combinations. were found to have significant effect. The maximum ascorbic acid content (12.23 mg 100 g<sup>-1</sup> tomato pulp) at 12th day of storage were recorded in half ripen tomato covering with straw while it was minimum (4.77 mg 100 g<sup>-1</sup> tomato pulp) in mature green tomato (Table 3). At the 0th, 3rd and 12th day of storage, there was a significant interaction between maturity stages and ripening conditions in respect of ascorbic acid content of fruit pulp.

**pH of tomato juice:** The pH content of fruit pulp varied significantly in fruit of different maturity. It was found that pH increased with the advancement of ripening of fruit (Table 1). The highest pH value (4.63)

was observed in mature green tomatoes followed by half ripen (4.37) and full ripen fruit (4.27) respectively at 12 days of storage. similar result was also reported in pineapple by<sup>[2]</sup>.The effect of ripening conditions on pH of tomato were found significant at 0, 6 and 12 days of storage. The maximum pH value (4.45) was recorded in straw covering fruits and it was minimum (4.39) in case of use of CaC<sub>2</sub> + straw covering on 12<sup>th</sup> days of storage (Table 2). The combined effect of stages of maturity and ripening conditions was also found significant (Table 3). The highest pH content (4.71) was recorded in mature green tomatoes under covering with straw, while it was lowest (4.26) in full ripe tomatoes under the control treatment at 12th day of storage. The present findings is an agreement with the that of<sup>[9]</sup> who observed that pulp pH of mango was increased during storage.

**Total titrable acidity content of tomato pulp:** The total titrable acidity (%) in tomato pulp varied significantly in fruit of different maturity (Table 1). The half ripen tomato pulp contained highest quantity of total titrable acidity (0.48%) followed by full ripe

(0.47%) and mature green tomatoes (0.44%) at 9th day of observation. It was found that the titrable acidity content of tomato juice was increase with the advancement of ripening of fruit and reached at peak stage on 9th day and there after again started to decrease. Similar to the findings of<sup>[14,15]</sup>. Ripening conditions also had the effect on the titrable acidity content of tomato juice (Table 2). Results showed that titrable acidity content of tomato under all ripening conditions was increased certain days of storage and then sharply declined with the advancement of storage period. At 9th day of storage the highest quantity of acidity content (0.469%) was recorded in simple straw covering while it was minimum (0.46%) in control condition. The total titrable acidity content was significantly influenced by the combined effect of stages of maturity and ripening conditions (Table 3). The maximum content of total titrable acidity (0.48%) at 9th day of storage was recorded in half ripen tomatoes with CaC<sub>2</sub>+straw covering, while it was minimum (0.45%) in mature green tomatoes under the control treatment.

**Sugar content of tomato pulp:** Significant variation among the tomato fruits of different maturity stages were recorded in respect of reducing sugar content of the fruit pulp. It estimated that reducing sugar content was increased with the advancement of ripening of fruit. Full ripen tomato contained the highest quantity of reducing sugar while the mature green tomato contained the lowest quantity at all time of observations (Table 4) also Dalai *et al.*<sup>[5]</sup> also observed similar result. The change in reducing sugar content was significantly influenced also by the ripening conditions. The highest increase in reducing sugar content was recorded under CaC<sub>2</sub>+straw covering condition, While the control was found to show less value in this regard (Table 5). The combined effect of stages of maturity and ripening conditions significantly effect the reducing sugar content of the fruit (Table 6). The highest quantity of reducing sugar content (4.44%) at 12th day of storage was recorded in full ripen tomato fruits under CaC<sub>2</sub> use with straw covering treatment while it was minimum (3.83%) in mature green fruit under control treatment at 12th day of storage. Significant variations among different stages of tomato fruits were recorded in respect of non reducing sugar content of the tomato pulp. Tomatoes of all stages of maturity were found to

increase in quantity of non reducing sugar during process of ripening and was in highest value at 6 day of observation (1.64). It was then found to gradually decrease with advancing ripening and was lowest (0.586) at 12th (Table 4).<sup>[14]</sup> also observed similar result. Ripening condition did not significantly affect non reducing sugar content of tomato pulp during the storage period. The combined effect of stages of maturity and ripening conditions was found significant on the change in non reducing sugar content of tomato pulp. The highest quantity of non reducing sugar content (1.86%) at 6th day of storage was found in full ripe tomatoes under covering with straw treatment while it was lowest (1.40%) in mature green fruits under CaC<sub>2</sub> use with straw covering treatment (Table 6). The non-reducing sugar content was increased from mature green to full ripen stage and such increase might be due to break down of starch and there after formation of non-reducing sugar. Total sugar content of tomato pulp varied significantly in fruits of different maturity. It was found that total sugar content was increased with the advancement of ripening of fruits irrespective of maturity condition. The highest quantity of total sugar (4.03%) was recorded in full ripen tomatoes while it was lowest quantity (3.30%) in mature green tomatoes at 12th day of storage. Winsor *et al.*<sup>[19]</sup> obtained similar result also. Ripening condition was found to be affecting significantly total sugar content of tomato at different storage duration (Table 5). The highest quantity of total sugar content (4.91%) was recorded in tomatoes under CaC<sub>2</sub>+ straw covering treatment at 12th day of storage followed by the covering with simple straw treatment (4.82%) and it was lowest in mature green tomato (4.72%) under control condition. The combined effect of stages of maturity and ripening conditions significantly affected the total sugar content of tomato during storage (Table 6). At 12th day of storage the highest quantity of total sugar content (5.01%) was recorded in full ripe tomatoes under CaC<sub>2</sub>+straw covering treatment and lowest quantity of total sugar (4.69%) was recorded in mature green tomatoes under simple straw covering treatment.

The gradual increase in total sugar content found in this experiment is an agreement the results of<sup>[18]</sup>. The increase in total sugar content might be due to conversion of starch in to sugars.

Table 4: Main effect of stages of maturity on the percent of reducing sugar, non- reducing sugar and total sugar content of tomato at different days of storage

Treatment	Days of storage														
	Reducing sugar (%)					Non-reducing sugar (%)					Total sugar (%)				
	0	3	6	9	12	0	3	6	9	12	0	3	6	9	12
Mature green	2.390	2.990	3.450	3.640	3.860	0.910	1.210	1.410	1.24	0.878	3.300	4.210	4.860	4.870	4.730
Half ripen	2.660	3.210	3.510	3.660	3.990	0.960	1.250	1.460	1.27	0.877	3.620	4.460	5.000	4.930	4.870
Full ripen	2.990	3.250	3.570	3.700	4.340	1.030	1.330	1.640	1.28	0.586	4.030	4.580	5.210	4.980	4.920
LSD (0.05)	0.001	0.032	0.032	0.000	1.045	0.001	0.032	0.032	--	0.001	0.032	0.045	0.045	0.045	0.032
LSD (0.01)	0.014	0.044	0.044	0.014	0.062	0.014	0.044	0.044	--	0.014	0.044	0.062	0.062	0.062	0.044

Table 5: Effect of ripening conditions on the percent of reducing, non-reducing and total sugar content of tomato at different days of storage

Treatment	Days of storage														
	Reducing sugar (%)					Non-reducing sugar (%)					Total sugar (%)				
	0	3	6	9	12	0	3	6	9	12	0	3	6	9	12
Uncovered	2.650	3.110	3.48	3.610	4.010	0.950	1.25	1.50	1.27	0.787	3.600	4.360	4.99	4.890	4.790
Covering(straw)	2.680	3.160	3.52	3.660	4.060	0.970	1.25	1.52	1.25	0.763	3.650	4.410	5.04	4.920	4.820
CaC2+straw															
Covering	2.720	3.180	3.53	3.720	4.120	0.980	1.29	1.51	1.26	0.790	3.700	4.480	5.04	4.980	4.910
LSD (0.05)	0.001	0.032	--	0.001	0.045	0.001	--	--	--	0.001	0.032	0.045	--	0.045	0.032
LSD (0.01)	0.014	0.044	--	0.014	0.062	--	--	--	--	0.014	0.044	0.062	--	0.062	0.044

Table 6: Combined effects of stages of maturity and ripening conditions on the percent of reducing, non reducing and total sugar content of tomato at different days of storage

Treatment Combinations	Days of storage														
	Reducing sugar (%)					Non-reducing Sugar (%)					Total sugar (%)				
	0	3	6	9	12	0	3	6	9	12	0	3	6	9	12
M <sub>1</sub> T <sub>1</sub>	2.390	2.960	3.420	3.610	3.830	0.900	1.200	1.420	1.230	0.900	3.290	4.160	4.840	4.840	4.730
M <sub>1</sub> T <sub>2</sub>	2.390	2.990	3.440	3.630	3.850	0.920	1.200	1.400	1.230	0.833	3.310	4.190	4.840	4.860	4.690
M <sub>1</sub> T <sub>3</sub>	2.380	3.030	3.480	3.670	3.880	0.910	1.240	1.400	1.250	0.900	3.290	4.270	4.880	4.920	4.780
M <sub>2</sub> T <sub>1</sub>	2.610	3.170	3.480	3.600	3.940	0.950	1.250	1.450	1.310	0.877	3.580	4.420	4.930	4.910	4.810
M <sub>2</sub> T <sub>2</sub>	2.680	3.220	3.530	3.660	4.010	0.950	1.230	1.490	1.270	0.853	3.630	4.440	5.020	4.930	4.870
M <sub>2</sub> T <sub>3</sub>	2.680	3.250	3.520	3.730	4.040	0.980	1.260	1.530	1.230	0.900	3.660	4.520	5.060	4.960	4.940
M <sub>3</sub> T <sub>1</sub>	2.920	3.200	3.550	3.630	4.250	1.000	1.300	1.640	1.280	0.583	3.920	4.500	5.180	4.910	4.830
M <sub>3</sub> T <sub>2</sub>	2.970	3.280	3.580	3.700	4.310	1.050	1.330	1.680	1.260	0.603	4.020	4.610	5.250	4.960	4.920
M <sub>3</sub> T <sub>3</sub>	3.100	3.280	3.590	3.760	4.440	1.040	1.360	1.600	1.200	0.570	4.140	4.640	5.190	5.050	5.010
LSD (0.05)	0.017	0.055	0.055	0.017	0.017	0.017	0.055	0.055	0.077	0.017	0.055	0.077	0.077	0.077	0.005
LSD (0.01)	0.024	0.075	0.075	0.024	0.107	0.024	0.075	0.075	0.107	0.024	0.075	0.107	0.107	0.075	0.075
CV (%)	0.810	0.800	1.090	0.460	0.960	2.230	3.000	1.570	3.520	1.560	0.950	1.050	0.970	0.870	0.760

Maturity stages  
M1: Mature green  
M2: Half ripen  
M3: Full ripen

Ripening condition  
T1: Uncovered  
T2: Covering with straw  
T3: Treated with CaC2+ covering with straw

Table7: Main effect of stages of maturity on percent TSS, TSS and acidity ratio content of tomato at different days of storage

Treatment	Days of storage									
	Total soluble solid (TSS %)					TSS and acidity ratio				
	0	3	6	9	12	0	3	6	9	12
Mature green	5.850	7.220	8.060	8.590	8.860	14.59	16.07	18.26	18.93	20.00
Half ripen	6.540	7.520	8.280	8.670	8.920	15.60	17.02	17.78	18.02	19.29
Full ripen	6.820	7.880	8.450	8.760	8.980	0.508	0.158	0.179	0.141	0.077
LSD (0.05)	0.032	0.071	0.077	0.045	0.032	0.508	0.158	0.179	0.141	0.077
LSD (0.01)	0.044	0.097	0.107	0.062	0.044	0.699	0.218	0.246	0.195	0.107

Table 8: Main effect of ripening conditions on percent TSS, TSS and acidity ratio content of tomato at different days of storage

Treatment	DS: Days of storage									
	Total soluble solid (TSS %)					TSS and acidity ratio				
	0	3	6	9	12	0	3	6	9	12
Uncovered	6.32	6.46	8.24	8.63	8.92	15.02	16.81	18.15	18.52	19.62
Covering with straw	6.39	7.56	8.25	8.69	8.91	15.36	16.77	18.19	18.55	19.65
CaC <sub>2</sub> +straw										
Covering	6.50	7.60	8.29	8.71	8.93	15.78	16.81	18.17	18.69	19.66
LSD (0.05)	0.032	0.071	--	0.045	--	0.508	0.154	--	0.141	--
LSD (0.01)	0.044	0.097	--	0.062	--	0.699	0.218	--	--	--

Table 9: Combined effect of stages of maturity and ripening conditions on the percent TSS, TSS and acidity ratio content of tomato at different days of storage

Treatment Combinations	Days of storage									
	Total soluble solid (TSS)					TSS and acidity ratio				
	0	3	6	9	12	0	3	6	9	12
M <sub>1</sub> T <sub>1</sub> 5.820	7.130	8.030	8.540	8.860	4.530	16.420	18.410	18.870	19.98	
M <sub>1</sub> T <sub>2</sub> 5.830	7.270	8.030	8.600	8.860	14.550	15.910	18.260	18.930	20.93	
M <sub>1</sub> T <sub>3</sub> 5.910	7.260	8.120	8.620	8.870	14.690	15.870	18.120	19.010	20.02	
M <sub>2</sub> T <sub>1</sub>	6.420	7.430	8.270	8.590	8.920	15.190	16.870	17.500	17.940	19.32
M <sub>2</sub> T <sub>2</sub>	.510	7.520	8.230	8.710	8.916	15.600	16.940	17.860	18.080	19.27
M <sub>2</sub> T <sub>3</sub> 6.690	7.620	8.350	8.720	8.930	16.020	17.250	17.890	18.040	19.27	
M <sub>3</sub> T <sub>1</sub> 6.710	7.830	8.440	8.750	8.990	15.330	17.120	18.460	18.760	19.57	
M <sub>3</sub> T <sub>2</sub> 6.840	7.890	8.480	8.760	8.950	15.920	17.460	18.440	18.640	19.66	
M <sub>3</sub> T <sub>3</sub> 6.920	7.920	8.420	8.780	9.000	16.640	17.320	18.510	19.030	19.71	
LSD (0.05)	0.050	0.122	0.134	0.077	0.055	0.879	0.274	0.310	0.245	0.134
LSD (0.01)	0.075	0.169	0.185	0.107	0.075	1.211	0.377	0.427	0.337	0.185
CV (%)	0.600	0.950	0.900	0.570	0.260	3.300	0.940	0.980	0.760	0.400

Maturity stages  
M1: Mature green  
M2: Half ripen  
M3: Full ripen

Ripening condition  
T1: Uncovered  
T2: Covering with straw  
T3: Treated with CaC<sub>2</sub>+ covering with straw

**TSS content of tomato pulp:** TSS is one of the most important quality factors for most of fruit. TSS of 4.80-8.80% indicates the highest quality of tomato<sup>[9]</sup>. In the present experiment, the TSS content of tomato juice varied significantly in fruits of different maturity. It was found that full ripen tomato contained the highest quantity of TSS (6.82%) while it was lowest (5.85%) mature green tomatoes at harvest (Table 7). For all maturity stages, TSS increased gradually with the advancement of ripening process.<sup>[19]</sup> also reported similar trend of results. Ripening conditions were also found to have significant effects on change in TSS content of tomato juice at 0, 3 and 9th day of storage (Table 8). The highest quantity of TSS content (8.71%) was recorded in CaC<sub>2</sub>+Straw covering treatment while it was lowest (8.63%) in control condition at 9th day of data recording.

The TSS content was also found to be significantly influenced by the combined effect of stages of maturity and ripening conditions during the whole period of ripening (Table 9).

The highest content of TSS content (9.00%) at 12th day of storage was recorded in full ripen tomatoes under CaC<sub>2</sub>+straw covering treatment whereas, it was minimum (8.86%) in mature green tomatoes under control treatment. Similar result, gradual increase of TSS content during advancing stages of ripening and storage which was possibly due to hydrolysis of starch into sugar.

**TSS and acidity ratio of tomato pulp:** It was found that highly significant effect of maturity stages of tomatoes on TSS and acidity ratio in tomato pulp (Table 9). Result showed that full ripen tomatoes contained the maximum TSS and acidity ratio (15.96) at 0 day of observation while it was minimum in mature green tomatoes (14.59) Singleton, V.L.<sup>[13]</sup> also reported similar results in pineapple fruit. TSS and acidity ratio was increased with the advancement of ripening of fruits.<sup>[4]</sup> also reported similar result in pineapple fruits. The ripening conditions were found to significantly affect the change in TSS and acidity ratio only at 0th and 9th day of storage. The highest TSS and acidity

ratio (18.69) was observed for CaC<sub>2</sub> use with simple straw covering treatment (18.55) while it was minimum (18.52) in control treatment at 9th day of storage (Table 8). The TSS and acidity ratio also found to be significantly influenced by the combined effect of stages of maturity and ripening conditions (Table 9). The TSS and acidity ratio (19.03) were recorded in full ripe tomatoes under CaC<sub>2</sub> use with straw covering treatment and the lowest (17.94) was recorded in half ripe tomatoes under control treatment at 9th day of storage.

### DISCUSSION

The percentage of pH, titrable acidity, reducing sugar, total sugar, TSS, TSS and acidity ratio were found to increased with gradual advancement of time, irrespective of maturity stages while percentage of vitamin- C and non reducing sugar were found to decreased with progressing time of storage. The ripening conditions also showed significant influenced on different parameters studied . The highest value of titrable acidity (0.455%) were recorded in tomatoes of uncovered treatment and reducing sugar (4.12%) non-reducing sugar (0.790%), total sugar (4.91%) and TSS (8.93%) were recorded by CaC<sub>2</sub>+ straw covering treatment and vitamin-C (8.33mg /100g), pH (4.45) and TSS and acidity ratio (19.66) by simple straw covering treatment at final day of observation. On the contrary, the lowest values of vitamin-C (8.29 mg/100g), reducing sugar (4.01%), total sugar (4.79%) and TSS and acidity ratio (19.62) were recorded by uncovered tomatoes and pH (4.39) were recorded by CaC<sub>2</sub>+ straw covering treatment, while titrable acidity (4.33%), non-reducing sugar (0.763%) and total soluble solid (8.91%) by simple straw covering at final day of observation. The value of all the above parameters except vitamin-C and non-reducing sugar were found to increased gradually with the advancement of ripening process irrespective of different keeping conditions. The combined effect of maturity and ripening conditions also influenced significantly different on chemical characters of tomato during ripening. The full ripen tomato placed over CaC<sub>2</sub> and covered with straw gave highest titrable acidity (0.462%), reducing sugar (4.44%), non-reducing sugar (0.900%), total sugar (4.62%), TSS (8.70%) and TSS & acidity ratio (20.02) at final day of observation. The mature green tomatoes kept in uncovered condition showed the lowest performances in respect of vitamin-C (4.77 mg 100 g<sup>-1</sup>), titrable acidity (0.443%), reducing sugar (3.83%), non-

reducing sugar (0.583%), total sugar (4.73%) and TSS (8.86%) at final day of observation.

### CONCLUSION

It is possible to maintaining chemical quality of tomato during ripening and marketing. The most suitable stage for long distance marketing was mature green tomato and for fresh consumption is full ripen. For early ripening and color development CaC<sub>2</sub> + straw covering treatment was observed most suitable for mature green tomatoes.

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