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Influence of Harvesting Stage and Storage Temperature on Nutritional Quality of Tomato (*Lycopersicon esculentum* Mill) cv. PKM-1

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Premise of Research: It is found that the nutritional quality of fruits varies with the harvesting stage and the storage temperature. Hence, a study was conducted to evaluate the nutritional quality of a popular tomato cultivar in South India, PKM-1 harvested at different maturity stages and during storage.

Methodology: Tomato fruits were harvested at mature green, yellow-green and red ripe stages and the nutritional quality of fresh tomatoes were determined. The fruits were stored at room temperature and in refrigerator at 6^{o}C and the changes in biochemical parameters were estimated.

Pivotal Results: Ascorbic acid, total sugars and lycopene contents increased during ripening and were found to be highest in red ripe stage. Titrable acidity and total phenols were highest in mature green tomatoes and decreased during ripening. Storage studies revealed that ascorbic acid, titrable acidity and total phenols decreased during storage. Total sugars and lycopene contents increased during storage.

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Conclusions: Tomato fruits stored at 6^{o}C showed better nutritional value due to lesser change in nutrient content. The study revealed that the nutritional quality of tomato harvested at red ripe stage had the highest nutritional value and a low temperature of 6^{o}C favoured better shelf-life and is ideal for storage of harvested tomato.

Keywords: Tomato; harvesting stage; ascorbic acid; sugars; phenolics.

1. INTRODUCTION

Tomato (*Lycopersicon esculentum*) is one of the most consumed foods throughout the world. The area under tomato cultivation is increasing day by day as it is a short duration crop giving high yield and income to the farmers [1]. Tomato is consumed raw, in salads, or after cooking. Dietary intake of tomato and tomato products containing lycopene has been shown to be associated with a decreased risk of chronic diseases such as cancer and cardiovascular diseases [2,3]. Tomato also contains other natural antioxidants, including ascorbic acid and phenolic compounds. Antioxidants present in food can largely inhibit the harmful effects of free radicals in humans. Recently, enormous evidence is available to affirm that fruits and vegetables contain high concentrations of bioactive compounds including antioxidants which may be beneficial to health [4,5]. Several important changes occur in the ultra-structure of tomatoes during ripening, such as, synthesis of lycopene, production of flavour and aroma compounds, and increase in the ratio of citric to malic acid [6].

The maturity of harvested perishable commodities and the way in which they are handled, transported and marketed affect their storage life and quality [7]. Immature fruits are more subjected to shrivelling and mechanical damage, and are of inferior quality when ripe. Any fruit picked either too early or too late in its season is more susceptible to physiological disorders and has a shorter life than fruit picked at the proper maturity [8]. The most important quality criteria for tomatoes are red colour, firm but juicy texture, and good flavour. The metabolism of tomatoes continues, even after their detachment from the plant, when fruits have reached their red stage. They continue to ripen and finally deteriorate to a point where they become valueless [9]. It was observed that total soluble solids (TSS) increased during the initial days of storage, attained a peak value and then decreased [10,11]. Earlier studies reported an increase in sugar-acid ratio during storage of tomato fruits at ambient conditions [11,12]. During post-harvest storage, starch present in tomato fruits are hydrolyzed to soluble sugar such as glucose, fructose and sucrose [13].

Normally tomatoes are harvested at light red or breaker stage for distant transportation. Several studies have been conducted on storage behaviour and shelf life of tomatoes at varied temperature and conditions [12,14,15]. However, information on the changes in overall nutrients on storage of tomato fruits harvested at different ripening stages on PKM-1 tomato cultivar is scanty. This study was thus, conducted to determine the changes in the nutritional parameters on storage of PKM-1 tomato fruits harvested at mature green, yellow-green and red ripe stages. The objective of this work was to identify the optimum harvest maturity resulting in better quality and longer marketability of tomato.

2. MATERIALS AND METHODS

2.1 Fruit Sampling and Storage Treatments

PKM-1 tomato variety is cultivated throughout the Southern States of India especially in Tamil Nadu. This tomato variety was released by the Tamil Nadu Agricultural University during the year 1978. It is an induced mutant from a local variety called Annanji. It yields on an average, 32 t/ha in a duration of 135 days. The fruits are flat round with capsicum red color with prominent green shoulders even after ripening and weigh about 60-70 g. Fruits are firm and suitable for long distance transport. Though various research work on agricultural production have been conducted with this cultivar, the changes in biochemical parameters during the ripening process and storage are not studied in detail. Hence, this variety was selected for this study.

A field experiment was conducted during 2009-10 at the orchard in Agricultural College and Research Institute, Madurai, Tamil Nadu, India. The field is situated at an elevation of 152 m (above sea level) with 9°97' N latitude and 78°20' E longitude. A raised nursery bed was prepared by applying 10 kg farmyard manure

(FYM), 1 kg neem cake, 50 g VAM, 100 g superphosphate and 10 g Furadon per square metre. Certified seeds of tomato cv. PKM-1 were treated with 10 g *Pseudomonas fluorescens* and 2 g Carbendazim per kg of seeds 24 hours before sowing. Just before sowing, the seeds were treated with *Azospirillum* @ 10 g/ 100 g of seeds. Seeds were sown in lines at 10 cm apart in nursery beds and covered with sand. Field was ploughed to fine tilth and was prepared with the addition of FYM 25 t/ha and formed ridges and furrows at a spacing of 60 cm. *Azospirillum* (2 kg/ha) and Phosphobacteria (2 kg/ha) were also applied along with FYM. A basal dose of chemical fertilizers, NPK 75:100:50 Kg/ha, Borax 10 kg and Zinc sulphate 50 kg/ha were applied. Twenty five days old seedlings of tomato were transplanted on the sides of ridges at a distance of 45 cm. After 30 days of planting 75 kg N/ha was applied. Since no visible pest attack or disease was noticed, plant protection measures were not taken during the experimental period.

Tomato fruits were harvested at three maturity stages including mature green (turning), yellow-green (half ripen) and red ripe (full ripen) from the trial. Fruits of uniform size, free from pest and disease injuries, bruises and blemishes were selected, washed with water and dried with soft cloth. Normally, for household purpose, the purchased tomato fruits are stored in open condition at room temperature or wrapped in polythene bags and stored in refrigerator. Hence, samples harvested at different maturity stages were stored at two experimental temperatures. One part (1 kg) of tomatoes were placed as a single layer in a paper carton and kept open at ambient conditions prevailing in the laboratory temperature (28℃ ± 1) and the other part (1 kg) was wrapped with polythene bag and stored in a refrigerator maintained at cold temperature, 6℃ ± 1 [16].

2.2 Measurement of Nutrients

To study the effect of harvesting stage and storage temperature on nutrient contents, three fruits were taken randomly from each treatment on the day of harvest and subsequently on the 3rd, 6th, 9th and 12th days after harvest. Each fruit from a treatment represented a replicate. The different nutrients were assessed in each fruit.

Titrable acidity, ascorbic acid and lycopene contents were estimated following the method of Ranganna [17]. To determine titrable acidity, 10 g of the fruit sample was homogenised with about 25 ml of distilled water and filtered. The filtrate was collected and made up with distilled water. 10 ml of fruit extract was titrated against 0.1 N NaOH and the acidity was calculated and expressed as citric acid percentage.

Another 10 g of the fruit sample was blend with about 50 ml of 4% oxalic acid in a glass mortar and filtered. The filtrate was transferred to a 100 ml volumetric flask and made up with 4% oxalic acid. Known volume (10 ml) of this fruit extract was titrated against 2,4-dichlorophenol indophenol dye and the amount of ascorbic acid was calculated as mg (100 g)$^{-1}$ sample.

The lycopene content was measured in 5 g of fruit sample after extracting with acetone, till the pulp became colourless. Then, the acetone extract was mixed with 50 ml petroleum ether and 50 ml water in a separating funnel. Lycopene got transferred to the petroleum ether layer which was separated, dehydrated using anhydrous sodium sulphate and made up to 100 ml with petroleum ether. The absorbance of this solution was measured at 503 nm using a spectrophotometer.

Total sugars and phenols were extracted using ethanol. About 500 mg of the sample was homogenized in 5 ml of 80% ethanol using mortar and pestle. The homogenate was centrifuged and the supernatant was collected in a beaker. The residue was re-extracted with fresh 80% ethanol and centrifuged. The supernatant was pooled and evaporated to dryness. The residue was dissolved in distilled water (10 ml) and used for sugar and phenol estimation. Total soluble sugar was determined by Anthrone method [18]. The absorbance was read at 620 nm using spectrophotometer. Total sugar content was calculated using a standard graph and expressed as g (100 g)$^{-1}$ sample. Total phenol content was determined with the Folin-Ciocalteau reagent [19]. The absorbance was measured at 650 nm using spectrophotometer. Total phenol content was calculated using a standard graph and expressed as mg (100 g)$^{-1}$ sample.

The experiment was conducted in a completely randomized design with three replications and the data were analysed by using three factorial ANOVA at 5% LSD. All statistical analyses were conducted using AGRESS software.

3. RESULTS AND DISCUSSION

Harvesting stage and storage temperature play important role in increasing the shelf-life and

nutritional quality of fresh produce. The effect of temperature on shelf-life and nutritional quality of several tomato varieties have been studied earlier [20,21]. This experiment was conducted to study the effect of harvesting stage and storage temperature on nutritional quality of the most popular tomato variety PKM-1 cultivated in South India, especially in Tamil Nadu.

3.1 Titrable Acidity

Tomato cv.PKM-1 fruits were harvested at three different ripening stages (mature-green, half ripe and red-ripe) to assess the nutritional quality at harvest and on storage. The study revealed that titrable acidity decreased gradually from mature green to red ripe stage (Table 1). Mature green, half ripe and red ripe tomatoes had 0.91, 0.84 and 0.77% titrable acidity respectively. Generally, the level of acidity in the fruits decreases during ripening process [22]. The predominant acid in tomato is malic acid and is utilised as substrate for respiration during respiratory burst and further ripening, which is the reason for the decreasing trend in acidity during ripening [23]. Storage study showed that titrable acidity decreased gradually on storage up to 12 days. This is in corroboration with the findings of [11]. Least acidity of 0.51% was observed in tomato harvested at red ripe stage and stored at 28℃.

3.2 Ascorbic Acid

Ascorbic acid content significantly increased with advancing in harvest maturity (Table 2). Maximum ascorbic acid [21.54 mg (100 g)$^{-1}$] was found in red ripe and the least in mature green [10.2 mg (100 g)$^{-1}$] fruits at harvest. During storage, all treatments showed drastic decline in ascorbic acid content both at room temperature and in refrigerator. Highest [14.64 mg (100 g)$^{-1}$] ascorbic acid content at twelfth day of storage was observed in red ripe fruits stored at 6℃ and lowest [6.05 mg (100 g)$^{-1}$] in mature green fruits stored at room temperature. Ascorbic acid content was comparatively higher when stored in refrigerator than in room temperature. Similar trend was observed in cherry tomato also [24]. In tomato fruit, ascorbic acid content increases with maturity and stage of ripening, however once fruit reach the full ripe stage, ascorbic acid content starts to decline [25]. An increase in ascorbic acid content in fruit is thought to be an indication that the fruit is still in the ripening stage, while a decrease indicates a senescent fruit [26].

3.3 Total Soluble Sugars

Total sugar content of tomato fruits varied significantly at different ripening stages. It was found that total sugar content was increased with the advancement of ripening of fruits irrespective of maturity condition and storage temperature (Table 3). The highest quantity of total sugar [5.45 g (100 g)$^{-1}$] was recorded in red ripe tomatoes stored at room temperature; while it was lowest [3.84 g (100 g)$^{-1}$] in mature green tomatoes stored at 6℃ at twelfth day of storage. The gradual increase in total sugar content found in this experiment is agreement with previous studies with tomato and mango [13,27].

3.4 Lycopene

Lycopene is the most important antioxidant compound of the ripe tomato fruit and the one which determines its red colour. Lycopene content (Table 4) rapidly increased from half ripened stage [0.66 mg (100 g)$^{-1}$] to red ripe stage [2.04 mg (100 g)$^{-1}$]. Lycopene also increased during storage. Increased levels of lycopene in tomato during storage is due to ripening advancement of tomato fruits and conversion of chloroplasts to chromoplasts. A previous study also reported the increase in lycopene contents during storage [28]. The increasing in redness of tomatoes during ripening is due to lycopene accumulation [16]. Red ripe fruits stored for 12 days at 28℃ had the highest lycopene [2.98 mg (100 g)$^{-1}$]. Fruits stored at 6℃ showed lesser accumulation of lycopene compared to those stored at 28℃. Previous studies on storage at low temperature also reported lesser accumulation of lycopene in tomato [29].

3.5 Total Phenols

Total phenolic content gradually decreased with enhancement of ripening. Mature green and red ripe tomato had 43.77 and 28.2 mg (100 g)$^{-1}$ of total phenols (Table 5). A decrease in later stages of ripening was reported earlier [30]. Total phenols decreased significantly during storage of tomato fruits at room temperature and in refrigerator. Total phenol content of mature green tomato decreased from 43.77 mg (100 g)$^{-1}$ to 17.3 and 30.13 mg (100 g)$^{-1}$ when stored at 28 and 6^{o}C respectively. In red ripe fruits, total phenol decreased from 28.2 mg (100 g)$^{-1}$ to 16.47 and 24.33 mg (100 g)$^{-1}$ when stored at 28 and 6^{o}C respectively. The decrease in phenols might be due to senescence and breakdown of cell structure during storage as reported by [31].

Table 1. Effect of harvesting stage and storage temperature on titrable acidity (%) of tomato fruits

Treatment	Days					Mean
	0	3	6	9	12	
M1T1	0.91	0.81	0.72	0.59	0.58	0.72
M1T2	0.91	0.85	0.75	0.67	0.65	0.77
M2T1	0.84	0.74	0.6	0.57	0.53	0.66
M2T2	0.84	0.8	0.7	0.67	0.62	0.73
M3T1	0.77	0.72	0.61	0.54	0.51	0.63
M3T2	0.77	0.74	0.71	0.63	0.59	0.69
MEAN	0.84	0.78	0.68	0.61	0.58	0.7
Factor	**M**	**T**	**D**	**MT**	**TD**	**MD**	**MTD**
SED	0.003	0.003	0.005	0.005	0.006	0.008	0.011
CD (0.05)	0.007	0.006	0.009	0.010	0.013	0.0156	0.022

M- Maturity stage, M1- Mature green, M2- Yellow green, M3- Red ripe.
T- Storage temperature, T1- 28℃, T2- 6℃. D- No. o f days of storage.
SED-Standard Error of Difference between two means, CD- Critical Difference

Table 2. Effect of harvesting stage and storage temperature on ascorbic acid content [mg (100g)$^{-1}$] in tomato fruits

Treatment	Days					Mean
	0	3	6	9	12	
M1T1	10.2	9.07	8.17	6.57	6.05	8.01
M1T2	10.2	9.67	8.76	7.57	7.08	8.66
M2T1	15.43	13.91	12.48	9.95	9.32	12.22
M2T2	15.43	14.52	13.51	11.65	10.67	13.16
M3T1	21.54	19.76	17.57	14.32	12.65	17.17
M3T2	21.54	19.57	18.25	16.24	14.64	18.05
MEAN	15.72	14.42	13.12	11.055	10.07	12.88
Factor	**M**	**T**	**D**	**MT**	**TD**	**MD**	**MTD**
SED	0.122	0.100	0.158	0.173	0.223	0.273	0.386
CD (0.05)	0.244	0.199	0.315	NS	0.446	0.546	NS

M- Maturity stage, M1- Mature green, M2- Yellow green, M3- Red ripe.
T- Storage temperature, T1- 28℃, T2- 6℃. D- No. o f days of storage.
SED-Standard Error of Difference between two means, CD- Critical Difference

Table 3. Effect of harvesting stage and storage temperature on total sugar content [g (100g)$^{-1}$] in tomato fruits

Treatment	Days					Mean
	0	3	6	9	12	
M1T1	3.11	3.52	4.24	4.52	4.63	4.00
M1T2	3.11	3.19	3.49	3.76	3.84	3.48
M2T1	3.59	4.06	4.53	4.72	4.96	4.37
M2T2	3.59	3.76	3.92	4.06	4.16	3.90
M3T1	4.08	4.52	5.16	5.31	5.45	4.90
M3T2	4.08	4.13	4.23	4.30	4.37	4.22
MEAN	3.59	3.86	4.26	4.45	4.57	4.15
Factor	**M**	**T**	**D**	**MT**	**TD**	**MD**	**MTD**
SED	0.032	0.026	0.041	0.045	0.058	0.071	0.100
CD (0.05)	0.063	0.052	0.082	0.090	0.115	0.141	NS

M- Maturity stage, M1- Mature green, M2- Yellow green, M3- Red ripe.
T- Storage temperature, T1- 28℃, T2- 6℃.D- No. of days of storage.
SED-Standard Error of Difference between two means, CD- Critical Difference

Table 4. Effect of harvesting stage and storage temperature on lycopene content [mg (100 g)$^{-1}$] in tomato fruits

Treatment	Days					Mean
	0	3	6	9	12	
M1T1	0.35	0.41	0.93	1.32	1.34	0.87
M1T2	0.35	0.37	0.43	0.57	0.68	0.48
M2T1	0.66	0.73	1.67	1.84	2.11	1.4
M2T2	0.66	0.67	0.96	1.12	1.18	0.92
M3T1	2.04	2.13	2.24	2.62	2.98	2.4
M3T2	2.04	2.09	2.12	2.18	2.26	2.14
MEAN	1.02	1.07	1.39	1.61	1.76	1.37
Factor	**M**	**T**	**D**	**MT**	**TD**	**MD**	**MTD**
SED	0.010	0.008	0.013	0.014	0.018	0.022	0.031
CD (0.05)	0.020	0.016	0.026	0.282	0.036	0.045	0.063

M- Maturity stage, M1- Mature green, M2- Yellow green, M3- Red ripe.
T- Storage temperature, T1- 28℃, T2- 6℃. D- No. o f days of storage.
SED-Standard Error of Difference between two means, CD- Critical Difference

Table 5. Effect of harvesting stage and storage temperature on total phenol content [mg (100 g)$^{-1}$] in tomato fruits

Treatment	Days					Mean
	0	3	6	9	12	
M1T1	43.77	40.5	30.63	21.37	17.3	30.71
M1T2	43.77	48.43	40.6	35.6	30.13	39.71
M2T1	32.1	28.2	21.93	18.37	17.07	23.53
M2T2	32.1	30.23	28.13	26.6	25.03	28.42
M3T1	28.2	23.63	18.57	17.83	16.47	20.94
M3T2	28.2	27.83	26.53	25.23	24.33	26.42
MEAN	34.69	33.14	27.73	24.17	21.72	28.29
Factor	**M**	**T**	**D**	**MT**	**TD**	**MD**	**MTD**
SED	0.376	0.307	0.486	0.532	0.687	0.842	1.190
CD (0.05)	0.753	0.615	0.972	1.065	1.375	1.684	NS

M- Maturity stage, M1- Mature green, M2- Yellow green, M3- Red ripe.
T- Storage temperature, T1- 28℃, T2- 6℃. D- No. o f days of storage.
SED- Standard Error of Difference between two means, CD- Critical Difference

4. CONCLUSION

The experiments conducted have shown that the nutritional composition including total sugars, ascorbic acid, lycopene and phenolics of the tomato fruit is strongly influenced during different ripening stages. Ascorbic acid, sugars and lycopene contents showed their highest levels at the red ripe stage while titrable acidity and phenolics were highest at mature green stage. Hence, tomato fruit harvested at red ripe stage had highest nutritional quality. Low temperature is preferred for storing tomato fruits since, storage at 6°C caused less change in nutritional components.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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