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Original Research Article

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

ABSTRACT

Premise of research. It is found that the nutritional quality of fruits varies with the harvesting stage and the temperature of storage. 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°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 on storage. Total sugars and lycopene contents increased on storage.

Conclusions. Storage at 6°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°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. As it is a short duration crop and gives high yield, it is important from economic point of view and hence area under its cultivation is increasing day by day (Pedapati et al. 2013). 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

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cardiovascular diseases (Agarwal and Rao 2000; Willis and Wians 2003). 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. (Kaur and Kapoor 2001; Parashar et al. 2014). 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 (Grierson and Kader 1986).

The maturity of harvested perishable commodities has bearing on the way in which they are handled, transported and marketed, and their storage life and quality (Reid 1985). 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 in its season is more susceptible to physiological disorders and has a shorter life than fruit picked at the proper maturity (Kader 1994). 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 (Yanuriati et al. 1999). 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, however, 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 and the objective of this work is to identify the optimum harvest maturity resulting in better quality and longer marketability of tomato.

2. MATERIAL AND METHODS

2.1. Fruit sampling and storage treatments

Tomato fruits cv. PKM-1 were harvested at three maturity stages including mature green (turning), yellow-green (half ripen) and red ripe (full ripen) from the trials conducted at Agricultural College and Research Institute, Madurai during 2009-10. Fruits of uniform size, free from pest and disease injuries, bruises and blemishes were selected, washed with water and dried with soft cloth. Samples were assigned to two experimental conditions. One part (1kg) of tomatoes were placed as a

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single layer in a paper carton and kept at ambient conditions prevailing in the laboratory temperature ($28^{o}C \pm 1$) and the other part (1kg) was wrapped with polythene bag and stored in a refrigerator maintained at cold temperature, 6℃ ± 1 (Rai et al. 2012).

2.2. Measurement of nutrients

To study the effect of harvesting stage and storage temperature on nutrient contents, fruits from the two treatments were taken for analysis on the day of harvest and subsequently on the 3rd, 6th, 9th and 12th days after harvest. Titrable acidity, ascorbic acid and lycopene contents were estimated following the method of Ranganna (1977). Total sugars and phenolics were extracted using 80% ethanol. Total soluble sugars were determined by Anthrone method (Hedge and Hofreiter 1962) and total phenolic content was determined with the Folin-Ciocalteau reagent (Malik and Singh 1980). 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 analysis 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 low temperature on shelf-life and the effect of nutritional quality of several tomato varieties were previously studied (Moneruzzaman et al. 2009; Nour et al. 2014). 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. 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 (Helyes and Lugasi 2006). Storage study showed that titrable acidity decreased gradually on storage upto 12 days. Least acidity of 0.51% was observed in tomato harvested at red ripe stage and stored at $28^{o}C$.

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

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°C, T2- 6°C.

D- No. of days of storage.

3.2. Ascorbic acid

Ascorbic acid content significantly increased with advancing in harvest maturity (Table 2). Maximum ascorbic acid (21.54 mg100g^{-1}) was found in red ripe and the least in mature green (10.2 mg100g^{-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 mg100g^{-1}) ascorbic acid content at twelfth day of storage was observed in red ripe fruits stored at 6°C and lowest (6.05 mg100g^{-1}) in mature green stored at room temperature. Ascorbic acid content was comparatively higher when stored in refrigerator than in room temperature. In tomato fruit, ascorbic acid content increases with

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maturity and stage of ripening, however once fruit reach the full ripe stage, ascorbic acid content starts to decline (Mathooko 2003). 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 (Sammi and Masud 2007).

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

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°C, T2- 6°C.

D- No. of days of storage.

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 g100g^{-}

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^{1}) was recorded in red ripe tomatoes stored at room temperature; while it was lowest (3.84 g100g^{-1}) in mature green tomatoes stored at 6°C at twelfth day of storage. The gradual increase in total sugar content found in this experiment is agreement with previous studies (Raffo et al. 2002; Sood et al. 2011).

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

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°C, T2- 6°C.

D- No. of days of storage.

3.4. Lycopene

Lycopene is the most important antioxidant compound of the ripen tomato fruit and the one which determines its red colour. Lycopene content (Table 4) rapidly increased from half ripened stage (0.66 mg100g^{-1}) to red ripe stage (2.04 mg100g^{-1}). Lycopene also increased during storage.

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Increased levels of lycopene in tomato during storage is due to ripening advancement of tomato fruits and conversion of chloroplasts to chromoplasts Ghosh et al. 2014 also reported the increase in lycopene contents during storage. The increasing in redness of tomatoes during ripening is due to lycopene accumulation (Rai et al. 2012). Red ripe fruits stored for 12 days at 28°C had the highest lycopene (2.98 mg 100g^{-1}). Fruits stored at 6°C showed lesser accumulation of lycopene compared to those stored at 28°C. Previous studies on storage at low temperature also reported lesser accumulation of lycopene in tomato (Aljouni et al. 2001).

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

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°C, T2- 6°C.

D- No. of days of storage.

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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 $100g^{-1}$ of total phenols (Table 5). A decrease in later stages of ripening was reported earlier (Raffo et al. 2002). 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 $100g^{-1}$ to 30.71 and 39.71 mg $100g^{-1}$ when stored at 28 and 6°C respectively. In red ripe fruits, total phenol decreased from 28.2 mg $100g^{-1}$ to 20.94 and 26.42 mg $100g^{-1}$ when stored at 28 and 6°C respectively. The decrease in phenols might be due to senescence and breakdown of cell structure during storage, as was reported by (Ali et al. 2010).

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

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°C, T2- 6°C.

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D- No. of days of storage.

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.

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