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Short communication

Genotypic variability in tomato for total carotenoids and lycopene content during summer and response to post harvest temperature

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ABSTRACT

Lycopene is the major carotenoid responsible for fruit colour in tomato *(Lycopersicon esculentum* Mill.*)*. However, colour of the fruit is greatly affected by high temperature prevailing during fruit growth in the summer crop. To select a genotype suitable for summer conditions that can maintain colour better, a set of 52 tomato genotypes were evaluated for lycopene, total carotenoids and for TSS during summer in Bengaluru. Among the genotypes screened, IIHR 2892 recorded very high lycopene content (328.4mg/100g dry weight) and IIHR 2866 recorded very low lycopene content (25.2mg/100g dry weight). TSS values ranged from 2.6°Brix in cv. Vybhav to 7.0° Brix in IIHR 2866. In addition, study was carried out to determine the effect of postharvest temperature on biosynthesis of lycopene in five selected tomato cultivars (Arka Rakshak, Arka Samrat, Arka Ananya, Lakshmi and Abhinava). Tomatoes harvested at breaker stage were stored at 27° C, 35° C and 40° C for ripening. High temperature reduced lycopene content in tomato fruits. Lycopene synthesis in fruits was completely inhibited above 35°C. In this study, mean lycopene content in tomatoes stored at 27° C was 3-4 times higher than that in tomatoes stored at 40° C. This indicates that in tomatoes, temperature at which the fruits are stored after harvest, is a more important factor for colour development.

Key words: Tomato, temperature, total carotenoids, lycopene, total soluble solids (TSS)

Tomato is one of the widely consumed vegetables in the world. It is rich in compounds beneficial to health, like vitamins, carotenoids, lycopene and phenolic compounds (Palop *et al,* 2010; Kaur *et al,* 2013). Lycopene is a potent antioxidant and is thought to be responsible protect cells against oxidative damage, thereby lowering the risk of chronic diseases (Rao and Agarwal, 1999). In addition to its antioxidant properties, lycopene has also been shown to induce cell to cell communication and to modulate hormone/ immune systems and other metabolic pathways, which may also confer beneficial effects (Rao *et al,* 1998). Lycopene, a fat soluble carotenoid, is a precursor of β-carotene and has at least twice as much antioxidant capacity as β-carotene (Davis *et al,* 2003).

Tomato and its products are a major source of lycopene, and contribute significantly to carotenoid intake in humans. However, processing and storage conditions of tomato may cause lycopene degradation (Nguyen and Schwartz, 1999). Isomerization and oxidation are important reactions causing lycopene degradation. The first stage of degradation is a reversible isomerization of all trans-lycopene to the less colored, more oxidizable *cis* isomer. Environmental factors such as oxygen, light and temperature may be very important in isomerization and autoxidation of lycopene in tomato products. Tomatoes are dried mostly at high temperatures in the presence of oxygen; dried tomato products (e.g., tomato halves, slices, quarters and powders) show highest sensitivity to oxidation (Demiray *et al,* 2013). Apart from processing and storage conditions, growth environment also influences development of lycopene in tomatoes. High-altitude cultivars had higher lycopene content than cultivars of the plains (Chandra *et al,* 2012), mainly due to the low growth temperature in the high altitude regions. Lycopene content is also affected by solar radiation and high temperature in the plains sometimes results in yellow colour of the fruit rather than red (Chandra *et al,* 2012).

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Temperature has a significant influence on growth and development of tomato fruits (Ploeg and Heuvelink, 2005). Temperatures below 12° C and above 32° C strongly inhibit lycopene biosynthesis (Collins *et al*, 2006; Javanmardi and Kubota, 2006; Raffo *et al*, 2006; Helyes *et al*, 2007). High temperatures (35° C) specifically inhibit accumulation of lycopene due to stimulation of conversion of lycopene into β-carotene (Krumbein *et al*, 2006). Growth season and location are highly significant factors affecting lycopene concentration in tomatoes. Temperatures greater than 30° C lead to inhibition of lycopene synthesis in normal, red cultivars of tomato; when the temperature is lower than 30° C, lycopene synthesis is restored. Such effects of temperature are dependent on cultivar (Garcia and Barrett, 2006). Shi and Maguer (2000) reported that relatively high temperatures (38° C) inhibited lycopene production, while, low temperatures inhibited both fruit ripening and lycopene production. In this study, variation in lycopene content in 52 genotypes and the effect of postharvest temperature on lycopene biosynthesis in five cultivars was studied. Genotypes showing diversity in fruit colour were selected for assessing the variability during summer cultivation. Commercial cultivars with red coloured fruits were selected for postharvest temperature experiments, since, these are harvested at the breaker stage, and, full colour-development occurs only after harvest.

The experiment was carried out at Indian Institute of Horticultural Research, Bengaluru, during summer of 2012. Bengaluru is located at 13°58′ N latitude, 78° E longitude and 890m above mean sea level. Uniformly ripe healthy fruits, at the red ripe stage were harvested and used in the analysis. Fruits were homogenized in a blender. Total carotenoids and lycopene content was estimated by spectrophotometric method (Lichtenthaler, 1987). Total carotenoids and lycopene were estimated by extracting five grams of the homogenized tomato sample with acetone and calcium carbonate. Extraction was repeated till the residue turned white. All the extractions were carried out under low-light conditions. Carotenoids were partitioned to hexane, dried with sodium sulphate and absorbance was read at 470nm and 503nm using a spectrophotometer (T80+ UV/VIS Spectrophotometer, PG Instruments Ltd.). Results were expressed as mg per 100g dry weight, using Standards. Total soluble solids were measured using a digital refractometer (ARKO India Ltd., Model DG-NXT) and expressed as °Brix.

Data were subjected to analysis of variance using ANOVA, and means were compared, with critical difference at P≤0.05.

Significant differences were observed for lycopene and total carotenoid content among the genotypes used (Table 2). Lycopene content ranged from 25.2mg/100g dry weight in IIHR 2866, to 328.4mg/100g dry weight in IIHR 2892. Total carotenoid content also exhibited a similar trend. The range of lycopene content in the genotypes was found to be significantly higher than the range reported earlier by several workers for tomato cultivars (Kerkhofs *et al*, 2005; Toor and Savage, 2005; Adalid *et al*, 2010; Kotikova *et al*, 2011).

Significant differences in TSS were observed among genotypes. TSS ranged from 2.6° Brix in cv. Vybhav, to 7.0° Brix in IIHR 2866. TSS is a key determinant of quality in the crop, whether for use as fresh produce or for processing. Further, TSS also contributes strongly to tomato flavor and consistency (Kaur *et al*, 2013). TSS range observed in the genotypes was found to be significantly higher than the range reported by workers earlier for tomato cultivars (George *et al*, 2004; Javanmardi and Kubota, 2006; Rai *et al*, 2012). Based on lycopene content, the tomato

Table 1. Tomato genotypes used in the study with date of harvest and mean maximum and minimum temperatures during fruit growth period

Tomato genotypes	Date of harvest	Temperature during fruit growth period	
		Avg. Max.	Avg. Min.
IIHR 2195, IIHR 2197, IIHR 2199, IIHR 2200, IIHR 2201, IIHR 2202, IIHR 2852	27/06/2012	31.9°C	16.4°C
IIHR 2853, IIHR 2854, IIHR 2855, IIHR 2856	28/06/2012	31.9°C	16.5°C
IIHR 2858, IIHR 2859, IIHR 2860, IIHR 2861, IIHR 2862	29/06/2012	31.9°C	16.5°C
Vybhav, Nandi, Arka Rakshak, Arka Samrat, Arka Ananya, Lakshmi, US 3140, US 3380, Abhinava, IIHR 2891, IIHR 2890, IIHR 2889	06/07/2012	31.3°C	17.6°C
IIHR 2886, IIHR 2887, IIHR 2884, IIHR 2835, IIHR 2834, IIHR 2888, IIHR 2857, IIHR 2863, IIHR 2864, IIHR 2865, IIHR 2866, IIHR 2406, IIHR 2408, IIHR 2412, IIHR 2413, IIHR 2417, IIHR 2321, IIHR 2876, IIHR 2827, IIHR 2622, IIHR 2828, IIHR 2657, IIHR 2885, IIHR 2892	07/07/2012	31.3°C	17.6°C

Table 2. Variation in total carotenoids, lycopene content and TSS of 52 tomato genotypes cultivated during summer of 2012

Tomato genotype	Total carotenoids (mg/100g dry weight)	Lycopene (mg/100g dry weight)	TSS (°Brix)
IIHR 2892	529.2	328.4	4.4
IIHR 2876	505.5	319.1	4.3
IIHR 2890	482.8	302.4	3.3
Abhinava	466.3	286.5	3.8
IIHR 2889	454.9	284.3	3.5
Vybhav	454.4	283.8	2.6
IIHR 2828	424.6	264.7	4.1
IIHR 2861	418.2	263.0	4.3
IIHR 2417	392.2	249.6	5.2
IIHR 2321	389.9	235.3	4.7
IIHR 2827	363.7	230.7	3.3
IIHR 2860	367.8	223.7	5.7
IIHR 2657	358.1	222.5	5.1
US 3380	355.9	218.0	3.2
Lakshmi	346.5	211.0	3.6
IIHR 2858	346.4	204.7	5.3
IIHR 2891	329.3	203.9	4.3
Nandi	335.6	199.4	3.2
IIHR 2412	316.9	193.5	4.1
IIHR 2888	308.7	189.1	4.3
IIHR 2408	304.2	187.7	3.1
US 3140	315.4	186.7	2.9
IIHR 2622	298.3	178.8	4.6
IIHR 2884	287.5	178.4	4.6
IIHR 2413	281.1	178.0	6.0
IIHR 2835	284.5	171.3	5.3
IIHR 2886	276.9	168.8	4.2
IIHR 2887	260.3	165.9	4.5
Arka Samrat	258.0	158.1	4.2
IIHR 2854	259.5	155.5	4.7
Arka Rakshak	252.5	151.6	3.2
IIHR 2857	265.3	151.5	5.5
IIHR 2853	246.4	149.9	4.8
IIHR 2885	244.2	148.2	4.1
Arka Ananya	243.9	145.5	4.1
IIHR 2834	225.0	133.3	3.9
IIHR 2862	225.0	131.9	5.6
IIHR 2195	229.4	130.5	4.5
IIHR 2863	199.2	118.7	5.8
IIHR 2855	201.8	114.9	3.9
IIHR 2197	198.2	111.5	4.9
IIHR 2859	173.2	100.7	5.1
IIHR 2856	160.3	96.3	4.5
IIHR 2201	156.7	85.7	4.9
IIHR 2202	148.7	81.8	5.1
IIHR 2199	137.7	78.1	5.4
IIHR 2200	128.6	71.4	5.5
IIHR 2852	126.3	69.3	5.1
IIHR 2406	146.4	52.1	4.9
IIHR 2865	140.2	45.3	3.5
IIHR 2864	141.4	44.7	4.5
IIHR 2866	98.2	25.2	7.0
Mean	285.8	170.8	4.5
CD *(P=0.05)*	25.2	17.1	0.2

genotypes were divided into six groups (Table 3). In the highest (>300mg/100g dw) and lowest (<50mg/100g dw) lycopene content groups, only three genotypes each were present. A majority of the genotypes fell in the group 100-200mg/100g dw lycopene content.

Results on the effect of postharvest temperature on lycopene biosynthesis in five tomato cultivars, viz., Arka Rakshak, Arka Samrat, Arka Ananya, Lakshmi and Abhinava, indicated significant difference for total carotenoids and lycopene content (Table 4). At 27°C, all genotypes recorded highest total carotenoids and lycopene. With increase in temperature, total carotenoids and lycopene content decreased in all the genotypes. Arka Rakshak showed highest reduction in total carotenoids and lycopene content. Arka Ananya, followed by Arka Samrat, recorded lower reduction in total carotenoids and lycopene content. 'Lakshmi' and 'Abhinava' exhibited higher total carotenoids and lycopene at all the temperatures, compared to the other genotypes. Mean lycopene content of tomatoes stored at 27°C was 3-4 times higher than that at 40°C. Better lycopene content was recorded in cv. Abhinava at 35°C, and in cv. Lakshmi at 40°C. Toor and Savage (2006) reported that storage at lower temperatures (7°C) inhibited accumulation of lycopene in tomatoes, whereas, lycopene level in light-red tomatoes increased upto 3-fold at a storage temperature of 15-25°C. Farneti *et al* (2012) concluded that storage of tomatoes at temperatures below 12°C induced lycopene degradation. Effect of high temperature (above 30°C) on lycopene content was reported to be cultivar-specific (Garcia and Barrett, 2006). Shi and Maguer (2000) reported that relatively high temperatures (38°C) inhibited lycopene production. Similar inhibition was also observed in this study at 40°C. Further, results indicated that irrespective of the field temperature experienced, colour development in tomato was largely controlled by storage temperature in fruits harvested at the breaker stage. Total carotenoids ($r = -0.9106$) and lycopene ($r = -0.9143$) were seen to be strongly and negatively correlated with temperature in this experiment. Such strong relationship at the post-harvest stage indicates the importance of ripening temperature for colour development in tomato.

A wide variation exists for lycopene content among tomato genotypes. IIHR 2892 was found to be superior in terms of lycopene content compared to other genotypes. Results show that post-harvest environmental conditions showed be considered carefully for development of good colour in tomato fruit. Variation in lycopene content in tomato is controlled by both genetic and environmental conditions (like temperature and light). This study confirms that tomatoes contain significant amounts of lycopene which may vary with post harvest

Table 3. Grouping of genotypes based on lycopene content

Group	Genotypes
I (> 300mg/100g dw)	IIHR 2892, 2890, 2876
II (250-300mg/100g dw)	Abhinava, IIHR 2889, Vybhav, IIHR 2828, IIHR 2861
III (200-250mg/100g dw)	IIHR 2417, IIHR 2321, IIHR 2827, IIHR 2860, IIHR 2657, US 3380, Lakshmi, IIHR 2858, IIHR 2891
IV (150-200mg/100g dw)	Nandi, IIHR 2412, IIHR 2888, IIHR 2408, US 3140, IIHR 2622, IIHR 2884, IIHR 2413, IIHR 2835, IIHR 2886, IIHR 2887, Arka Samrat, IIHR 2854, Arka Rakshak, IIHR 2857
VI (100-150mg/100g dw)	IIHR 2853, IIHR 2885, Arka Ananya, IIHR 2834, IIHR 2862, IIHR 2195, IIHR 2863, IIHR 2855, IIHR 2197, IIHR 2859
VII (50-100mg/100g dw)	IIHR 2856, IIHR 2201, IIHR 2202, IIHR 2199, IIHR 2200, IIHR 2852, IIHR 2406
VIII (< 50mg/100g dw)	IIHR 2865, IIHR 2864, IIHR 2866

Table 4. Effect of temperature on total carotenoids and lycopene content

Tomato genotype	Total carotenoids mg/100g dry weight				Lycopene mg/100g dry weight			
	27°C	35°C	40°C	Mean	27°C	35°C	40°C	Mean
Arka Rakshak	196.9	79.7	75.8	117.5	121.1	41.5	39.4	67.3
Arka Samrat	169.6	104.3	71.0	115.0	99.5	56.4	35.1	63.7
Arka Ananya	193.3	114.5	89.3	132.4	114.2	65.0	47.6	75.6
Lakshmi	228.7	112.7	110.5	150.6	138.8	61.3	57.5	85.9
Abhinava	221.2	134.4	86.5	147.4	134.2	75.9	47.1	85.7
Mean	202.0	109.1	86.6	132.6	121.6	60.0	45.4	75.6
CD *(P=0.05)*								
Variety (V)		6.0				3.8		
Temperature (T)		3.6				2.3		
V x T		17.9				11.5		

temperature conditions. Storage at temperatures of 35° and 40° C inhibits accumulation of lycopene in tomatoes significantly, whereas, at 27ºC, lycopene content increases.

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