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Screening tomato varieties for phytonutrients productivity and yield performance

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Abstract

Tomatoes *(Lycopersicon esculentum* Mill*)* and other vegetables, bean and fruits contain a number of phytonutrients, which are a useful source of energy, metabolic structural material and antioxidants. Additionally, they may boost the immune system or encourage enzymes that detoxify carcinogens. However, varietal productivity with regard to number of fruits per plant and quantity of phytonutrients is largely unknown. A pot experiment was conducted to analyse variety productivity and fruit phytonutrient contents (lycopene, beta-carotene and ascorbic acid) such as contents and their relationships in 13 varieties of tomato. Ten varieties were obtained locally and 3 developed by USDA, viz. 97L63, 97L66 and 97L97 (with known high fruit beta-carotene and suited for use in processing applications). The seedlings raised in nurseries were later transplanted in pots (one plant per pot), 5 plants per variety. Lycopene and beta-carotene contents were analysed, using column chromatography and spectrophotometry. Ascorbic acid content was also analysed spectrophotometrically. The statistical analysis revealed that, *Hyb*-SC-3 and *Hyb-Himalata* varieties gave maximum fruit yield. Lycopene content was maximum in *Anupamam* and beta-carotene, in *New Uday* and all 3 USDA varieties. The variety *New Uday* also excelled in ascorbic acid content. The positive relationship ($r = 0.99$) between carotenoid biosynthesis and ascorbic acid content is not clear. Interestingly, the inverse correlation ($r = -0.72$) between beta-carotene and lycopene confirms that accumulation of beta-carotene in tomato occurs at the expense of lycopene as beta-carotene is downstream of lycopene in the biosynthetic pathway.

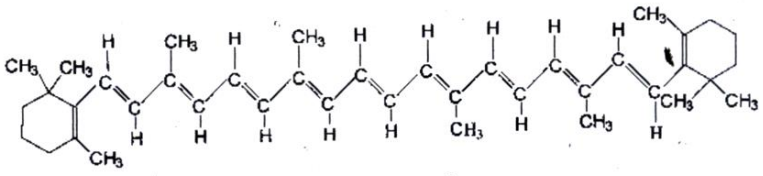
Key words: Antioxidants, column chromatography, *Lycopersicon esculentum,* spectrophotometry

Introduction

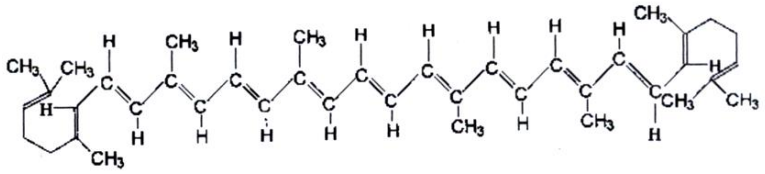
The tomato is rich in an antioxidant called lycopene, a compound principally found in tomatoes that protects cells from oxidants linked to causes of cancer. Beta-carotene, another antioxidant is also found in tomatoes. Lycopene and beta-carotene are carotenoid pigments (Fig. 1). In a laboratory test, lycopene was found to be twice as powerful as beta-carotene at neutralizing free radicals. Evidences show that people who eat a large amount of tomatoes and tomato products have a reduced risk for a number of cancers, including but not limited to prostate, lung and stomach, pancreatic, breast, cervical, colorectal, oral and esophageal cancers. Researchers theorize that lycopene, an antioxidant nutrient found in large amounts in tomatoes, may be responsible for this protective effect. Nutritionists and other health professionals have long advocated the cancer preventative benefits of a diet rich in fruits and vegetables. The findings of the Harvard Research Study support this recommendation and suggest that tomato-based foods may be especially beneficial regarding prostate cancer risk (Beecher, 1995; Bohm *et al.*, 1999; Giovanelli, 1999; Rao and Agarwal, 1999; Bramley, 2000; Ishida and Bieche 2000; Stefane, 2000).

The human body takes in beta-carotene (Fig. 1) and turns it into vitamin A, an essential nutrient that helps our bones and teeth grow strong and healthy. Beta-carotene is especially important in helping us to see clearly. Additionally, tomatoes are also an important source of ascorbic acid (Fig. 1) also

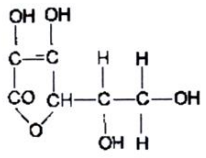
known as vitamin C, which boosts our immune system. Accordingly, efforts to develop varieties, that possess such phytonutrients to boost health. Stommel (1999) bred new tomatoes (97L63, 97L66 and 97L97). However, among the wide range of tomato varieties available, little is known about their phytonutrient productivity levels. Besides, it is also uncertain whether there is any relationship between yield performance and phytonutrient productivity.



β–CAROTENE



LYCOPENE



ASCORBIC ACID

Figure 1. Structural formula of beta-carotene, lycopene and ascorbic acid.

The objective of this study was to screen ten popular tomato varieties in India as well as three USDA varieties (specially developed for their high beta-carotene content) with regard to phytonutrient productivity and yield performance. The phytonutrients considered in the study were lycopene, beta-carotene and ascorbic acid contents. Correlation analysis was conducted to find out whether there is some relationship among these phytonutrients.

Materials and methods

A complete randomised block design pot experiment was conducted from 2001-2002 with 13 varieties of tomato, 10 local, viz- (1) *Anupamam*, (2) *Bharat Ratana*, (3) *Choice*, (4) *Durga*, (5) *Hyb-SC*-3, (6) *Hyb-Himalata*, (7) *New Uday*, (8) *Pusa Ruby*, (9) *Sarvoday*, (10) 10K-51, and 3 USDA varieties with high beta-carotene content and suitable for processing, viz- (11) 101-97L63, (12) 102-97L66 and (13) 103-97L97 in a screenhouse of the Department of Botany, Aligarh Muslim University, Aligarh, India. The local varieties, were obtained from the Sungro Seed Company, New Delhi; IARI, New Delhi and The Bombay Seed Company, Bombay and imported varieties from USDA, USA.

Prior to sowing, 4 kg homogenous mixture of soil and cow dung manure (3 : 1) was filled in each pot of 12 inch diameter. The soil was analysed for various characteristics and had a texture sandy loam, pH (1: 2) – 7.5, EC (1 : 2) -1.0 m mhos/cm, available N-238.2 kg N ha^{-1}, available P-12 kg P ha^{-1}, and available K-77 kg K ha^{-1}. Twenty seeds of each variety were sterilised in ethyl alcohol for an hour and then washed in the double distilled water. The seeds were sown in the pots on 20th October, 2001. After successful germination, four week old seedlings were transplanted into the pots at a rate of one plant per pot and three pots per variety. The pots were watered as and when required. At the time of fruit growth development, the plants were staked. After 75-90 days, all the plants started flowering. About 75% of plants showed ripening in the first week of March. Ripened fruits were harvested and the following parameters examined; 1) number of fruits per plant, 2), fresh weight per fruit, 3) fruit yield per plant, 4) lycopene content, 5) beta-carotene content, and 6) ascorbic acid content. Lycopene, beta-carotene and ascorbic acid contents of fresh tomato fruits were determined spectrophotometrically (Sadasivam and Mainckam,1992). The data were subjected to statistical analysis and Standard Errorors calculated.

Results and discussion

Highest number of fruits was recorded in *Hyb-SC-3* and *Hyb-Himalata* and the minimum in *Anupamam* and *Durga*. Average number of fruits per plant varied between 5-25 (Table 1). Maximum value was recorded in *Anupamam* variety followed by *Hyb-SC-3, Hyb-Himalata* and 10K-51. However, minimum value was given by a USDA variety 102-97L66. Maximum fruit yield was recorded in *Hyb-SC-3* variety (763.8 g). This variety was followed by *Hyb-Himalata* (608.0 g). The minimum yield was given by Durga. Lycopene content was maximum in *Anupamam* followed by *Hyb-SC-3, Bharat Ratana, Choice* and *Pusa Ruby*. On the other hand, as expected, all the three USDA varieties had lowest hycopene control. *Beta-carotene content* was highest in *New Uday, Anupamam* and all three varieties of USDA. The USDA varieties were specially bred to have more beta-carotene content. *New Uday* contained maximum ascorbic acid content. This was followed by Choice and a USDA variety 101-97L63. However, the minimum value was found in *Bharat Ratana*.

As far as a tomato fruit productivity is concerned the variety *Hyb-SC-3* excelled over all the varieties as the number of fruits per plant and the weight per fruit (25 x 30.55 g = 764 g) were maximum. This variety gave 2-6 times yield in comparison with other varieties. Lycopene content was maximum in *Anupamam*. However, the variety *Hyb-SC-3* may be adapted for lycopene production as the total fruit yield and lycopene content was maximum. As expected the USDA varieties exhibited minimum value of lycopene content. These varieties were specially bred by Stommel (1999) to contain lesser lycopene but higher beta-carotene content. Although, beta-carotene was considerably higher in USDA varieties,

Table 1. Number of fruits per plant, weight per fruit, fruit yield per plant, lycopene, beta-carotene and ascorbic acid contents of 13 varieties of tomato at harvest.

S. No.	Varieties	Parameters					
		Number of fruits per plant	Weight per fruit (g)	Fruit yield per Plant (g)	Lycopene content (mg/100g*)	Beta-Carotene content (µg/100g*)	Ascorbic acid content (µg/100g*)
1	*Anupamam*	5 ±2.6	32.4 ±9.8	162.4 ±25.5	14.13 ±0.15	1335.2 ±14.9	1962 ±18.2
2	*Bharat Ratana*	12 ±0.2	32.7 ±1.93	392.7 ±0.4	13.31 ±0.07	890.6 ±23.1	2741 ±19.0
3	*Choice*	10 ±1.2	27.2 ±4.95	272.0 ±6.0	13.01 ±0.14	1209.8 ±14.7	3378 ±36.6
4	*Durga*	7±0.1	17.4 ±4.36	122.0 ±4.4	11.19 ±0.08	1049.9 ±15.4	2277 ±32.1
5	*Hyb-SC-3*	25 ±0.9	30.6 ±3.98	763.8 ±3.6	13.56 ±0.12	1149.1 ±11.0	2574 ±37.0
6	*Hyb-Himalata*	20 ±2.8	30.4 ±3.15	608.0 ±8.9	12.66 ±0.08	1018.0 ±14.1	2870 ±54.1
7	*New Uday*	8 ±0.9	23.7 ±6.07	189.6 ±5.5	11.53 ±0.08	1565.7 ±19.4	3814 ±48.2
8	*Pusa Ruby*	13 ±0.8	26.1 ±1.05	339.3 ±0.9	12.98 ±0.13	998.7 ±11.6	2683 ±29.8
9	*Sarvoday*	10±0.1	21.8 ±2.73	218.3 ±0.3	12.62 ±0.15	1087.8 ±14.3	1889 ±31.2
10	10K-51	8 ±0.7	30.4 ±5.73	242.9 ±4.0	11.55 ±0.12	786.9 ±16.2	1692 ±15.1
USDA varieties							
11	101-97L63	13 ±1.5	23.3 ±7.2	303.0 ±10.8	7.73 ±0.06	1496.7 ±22.7	3186 ±18.0
12	102-97L66	15 ±1.8	11.2 ±1.54	167.6 ±2.7	8.34 ±0.04	1236 ±26.7	2556 ±32.1
13	103-97L97	11 ±1.0	24.0 ±8.93	264.4 ±8.9	7.14 ±0.15	1429.2 ±29.1	2925 ±18.4

Parameters presented as means of 3 replicates, ± indicates the Standard Error, * fresh tomatoes.

the Indian variety *New Uday* had highest content. Ascorbic acid (vitamin C) was again maximum in *New Uday*.

Results of correlation analysis among the lycopene, beta-carotene and ascorbic acid contents are presented in Figure 2. Although, lycopene and beta-carotene are tetraterpeniods, derived from isoprenes (Robbers *et al.*, 1996) and are very similar in structure (Fig. 1), it was surprising that the correlation was very low (r= - 0.1443) between the two. Both compounds, however, showed a partial positive correlation with ascorbic acid content (r = 0.5702, with lycopene and r = 0.5318 with beta-carotene). This shows that there is some relationship between the synthesis of the lycopene and beta-carotene on one hand and ascorbic acid on the other.

Interestingly, the inverse relationship (r= -0.7206) between beta-carotene and lycopene confirms that accumulation of beta-carotene in tomato occurs at the expense of lycopene, since beta-carotene synthesis is downstream of lycopene in the biosynthetic pathway. Typical red tomatoes contain high lycopene and low beta-carotene. Presence of the beta modifier gene boosts lycopene levels in tomatoes expressing the β gene, resulting in reddish orange fruit. USDA, and the local varieties evaluated in the experiment, do not express the modifier gene. The positive relationship (r = 0.9850) between carotenoid biosynthesis and ascorbic acid content is not clear (Fig. 2). There is variation for ascorbic acid content in tomato accessions and our data supports this. The data show that the absolute r-values tend to be higher for the USDA varieties because there is less variation between varieties for lycopene, beta-carotene, and ascorbic acid contents. Conversely, the local varieties are more diverse and resultant correlations are lower.

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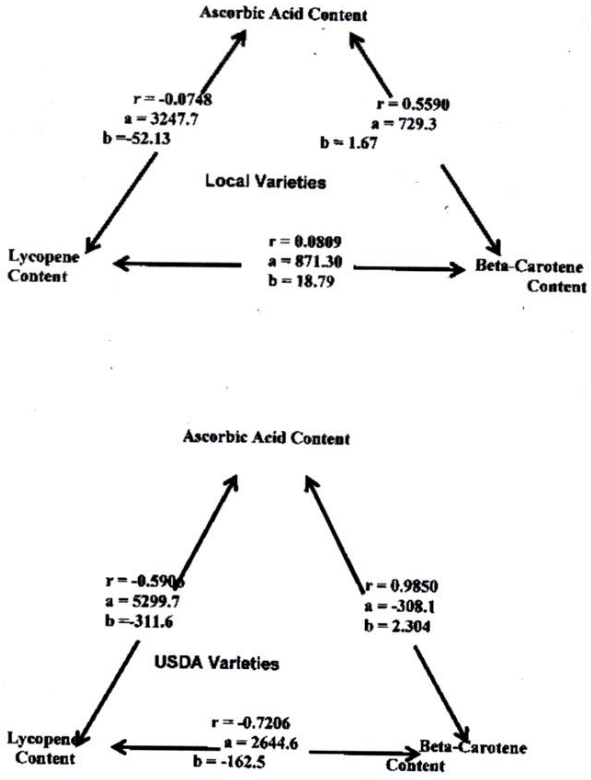

Figure 2. Correlation among the lycopene, beta-carotene and ascorbic acid contents in different varieties of tomato.

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