LYCOPENE CONTENT OF CALIFORNIA-GROWN TOMATO VARIETIES

D.M. Barrett and G. Anthon
Dept. of Food Science and Technology, University of California
Davis, CA 95616-8598

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Abstract

Tomatoes are an exceptionally rich source of lycopene, which has been reported to have beneficial antioxidant effects and may be a major factor in reducing the development of cancer and heart disease. Tomato breeders, growers and processors are therefore interested in the lycopene composition of different tomato varieties, and how composition is affected by growing region and season. Over 550 replicated and observational tomato variety samples were grown by Farm Advisers in Colusa, Fresno, Merced, San Joaquin, Stanislaus, Sutter and Yolo counties of California. Lycopene content was determined on tomato juice which had been exposed to a microwave hot break which simulates commercial hot break procedures. Lycopene content varied by county, with higher values in Stanislaus and Yolo during the early season and in Fresno, San Joaquin and Colusa in the mid season. Normalized values for lycopene content ranged from 84.1 to 172.9 mg/kg, or a 100% difference from lowest to highest. Some varieties stood out with particularly high values in most counties. Correlations between lycopene content and color (a*, a*/b*, chroma and L*) were investigated.

1. Introduction

Tomatoes are the world's second largest vegetable crop, in terms of production, and the United States is the world's largest producer and processor. The U.S. is responsible for 50% of the world production of processing tomatoes. In 1995, 85% of the tomatoes produced in the U.S. were processed into products such as paste, spaghetti and pizza sauce and salsa. All but about 15% of the U.S. crop is grown in California and in 1999 approximately 42% of the total loads processed were one of two leading varieties, Bos 3155 and Heinz 8892. Although the market is predominated by these two varieties, growers and processors are constantly evaluating new varieties to determine their yield and quality potential.

Tomatoes are composed primarily of water (93.5%), but they are also an important source of vitamins and minerals. In particular, tomatoes are rich in vitamins A, C, E and folate (a B vitamin), potassium and iron. Additional compounds of interest from a health standpoint include phytonutrients such as lycopene, flavonoids, phytosterols and various trace elements. The high rate of consumption of tomatoes in the U.S. makes them good contributors to the nutritional composition of the American diet. Lycopene has received particular interest of late due to its antioxidant properties. As an antioxidant, lycopene may be involved in cell growth and regulation of cell-cell communication. Antioxidants have been known to have beneficial effects on different forms of cancer, such as that of the GI tract, stomach, colon, rectum, bladder, pancreas, prostate, breast, lung, cervix, endometrium and ovary. In addition, there is some evidence of beneficial effects on heart disease. Although lycopene is a carotenoid, it is not utilized as provitamin A, as is ß-carotene. The carotenoid content of both raw and processed tomatoes has been determined and investigators have found lycopene in addition to phytoene, gamma-carotene, beta-carotene, z-carotene and neurosporene.

Lycopene typically exists in one of two isomeric forms, *cis* and *trans*. In the fresh tomato, 95.4% of the lycopene is in the *trans* configuration. Processing often induces isomerization of carotenoids to the *cis* isomer. This is true for ß-carotene, and the *cis* isomer of that compound is not as biologically active. In the case of lycopene, there does not appear to be as much processing-induced isomerization. Indeed, Nguyen and Schwartz (1998) found lycopene to be relatively heat resistant, and found less than 10% *cis* isomer in the processed tomato products analyzed.

Some studies indicate that the bioavailablility of lycopene may actually increase with processing. Gartner et al. (1997) found that serum lycopene increased 2.5x more from intake of the same amount of tomato paste as fresh tomatoes. This increase was thought to be due to better release from the tissue matrix due to processing. They found that lycopene was absorbed into chylomicrons in the form found in tomatoes and isomerized to *cis* in the serum and tissues. It was also found that isomerization increased the bioavailability of lycopene. The importance of *cis* vs. *trans* isomers, in terms of what the body can use, is still under investigation.

While the nutrition and medical professions work on determination of the bioavailability of lycopene in its various forms, tomato breeders are targeting increased content in new tomato varieties. UC Davis annually evaluates tomato varieties for the processing industry, and in 1999 we added lycopene analysis to the program. Our results from this study will be summarized in the following paper.

2. Materials and Methods

2.1. Varietal Selection

Varieties to be evaluated are selected following discussion with UC researchers, seed companies, growers and processors. The results of the previous year's research are reviewed and advice is given on which varieties to drop. New varieties are typically entered as observational materials for 1-3 years, then advanced to replicated trials if performance is desirable. Following 2-3 years in replicated trials, a variety is often adopted by the industry or dropped altogether. The following variety numbers were evaluated in 1999.

Replicated

Early — 3 locations (Colusa, Stanislaus, and Yolo Counties)
12 varieties
3 locations x 12 varieties x 2 replicates = 72 samples

Mid — 7 locations (Colusa, Fresno, Fresno MidLate, Merced, San Joaquin, Sutter, and Yolo Counties),
18 varieties
7 locations x 18 varieties x 2 replicates = 252 samples

Observational

Early — 3 locations (Colusa, Stanislaus, and Yolo Counties),
15 varieties
3 locations x 15 varieties x 1 replicate = 45 samples

Mid — 7 locations (Colusa, Fresno, Fresno MidLate, San Joaquin, Sutter, and Yolo Counties), 27 varieties
7 locations x 27 varieties x 1 replicate = 189 samples

Total sample number: 324 replicated + 234 observational = 558

2.2. Tomato Planting

Test sites were on cooperating grower fields, and were approximately one acre in size within a larger production area. Thirty meter-long plots were used at each site. A single replicate row was planted for observational varieties, while 4 replicate 30 m rows were planted for replicated varieties. Seed was obtained from seed companies and sublots sent to each participating county. Seed weights were obtained, and approximately the same number of seeds were planted in each plot at each county site. The cooperating grower planted the entire field with his equipment, except for the test sites, which were seeded at an appropriate seed depth with a hand-push planter. All cultural operations applied to the larger production field by the grower were also applied to the test site.

2.3. Fruit Sampling

Test sites were hand sampled 1 to 3 days prior to field harvest. Tomatoes were randomly selected by walking down the 30 m plot and harvesting from the middle section of plants. Approximately 15 kg of each varietal sample were harvested. Tomatoes were washed, towel dried and sorted for defects, then cut in half from stem to blossom end. One half of each fruit was placed in a Pyrex dish to achieve a net weight of approximately 1300 grams. The dish was immediately weighed, covered and heated in a commercial (1400 watt) microwave oven for 6 min at 100% power, followed by 6 min at 50% power. After cooking, the dish was placed in ice water to cool. Cooled samples were re-weighed, and water was added to compensate for evaporative losses during cooking. Seeds and skins were extracted using a lab pulper with a 0.8 mm screen. Microwave juice samples were frozen at -31^{o}C until analysis (approximately 1-3 months, depending on harvest date).

2.4. Sample evaluation

A modification of the method published by the Association of Official Analytical Chemists (AOAC) was used for lycopene analysis. The steps involved in the procedure were as follows:

1. Pipette 100 µl of tomato pulp into a screw cap tube using a 100 µl Drummond micropipettor.
2. Add 7.0 ml of 4:3 (v/v) Ethanol:Hexane using a repipettor. This solvent should be mixed fresh daily.
3. Cap and vortex tube then incubate, out of bright light, with occasional vortexing.
4. After 1 hr add 1.0 ml water to each sample and briefly shake.
5. Let samples stand 10 minutes to allow phases to separate and all air bubbles to disappear.
6. Remove a sample of the hexane layer and read OD 503 versus hexane in the spectrophotometer. To zero the spectrophotometer prepare one or two samples with 100 µl water instead of tomato pulp. It is important that the cuvette be rinsed with the hexane layer from this zero sample prior to reading the lycopene samples

Lycopene levels in the hexane extracts were calculated according to:

µg lycopene/g fresh wt. = $(A_{503} \times 537 \times 2.7)/(0.1 \times 172) = A_{503} \text{ x } 84.3$

where 537 g/mole is the molecular weight of lycopene, 2.7 ml is the volume of the hexane layer, 0.1 g is the weight of tomato added, and 172 mM^{-1} is the extinction coefficient for lycopene in hexane.

Duplicate samples (a and b) of lycopene were analyzed in each sample. Lycopene content was expressed as the average value in mg/kg fresh wt. of tomato juice. In addition, lycopene content was normalized to a °Brix value of 6.0, or (6.0/sample °Brix) x avg. lycopene content in sample. Finally, correlations between normalized lycopene content and color (Hunter a*, a*/b* L* value and chroma) were evaluated to see whether color is indicative of lycopene content.

3. Results and Discussion

Results are presented by season and type of trial (observational or replicated) in Tables 1-4. For each variety sample, the average normalized lycopene content (mg/kg fresh weight) and ranking from highest to lowest content is reported for each county. Average values for normalized lycopene content were also calculated over all growing regions.

It is interesting to note the variabililty in terms of county. In the early observational (Table 1) and replicated (Table 2) trials, where samples were grown in Colusa, Stanislaus and Yolo counties, the average normalized lycopene contents for all varieties grown in Colusa were lower than those in the other 2 counties. In the mid season observational trial (Table 3), normalized lycopene contents for tomatoes grown in Fresno (mid and late mid season) county were the highest. Lycopene contents (natural and normalized) from mid season replicated trials (Table 4) were highest in Fresno and San Joaquin, followed by Colusa county.

Normalized values for lycopene content ranged from 84.1 to 172.9 mg/kg fresh weight, or a 100% difference from lowest to highest. There were observational lines in both early and mid season trials which had higher values than the average replicated variety values. Some varieties stood out with high natural and normalized lycopene contents. These included:

Early observational	H9552, H9888, APT 723
Early replicated	CXD 204, Red Century 32
Mid observational	199Sun 6321, Brigade (std.), H9775
Mid replicated	H9492, H9491, CXD 199

Finally, we have plotted correlations between lycopene content and color values. Figure 1 shows the entire data set plotted against a* value, with a relatively poor correlation (r^2) of 0.1513. Likewise, a plot of the entire data set vs. a*/b* value has a correlation of 0.0156. However, if one takes average variety lycopene values from all growing regions for the early replicated trial, for example, the correlation improves, e.g. r^2= 0.4452. The correlation of a*/b* with lycopene in the mid season trial was still poor (r^2 = 0.0430) when average values were used. We also plotted Hunter c or chroma, which is a measure of color intensity or saturation and may reflect more accurately the changes in tomatoes as they mature. The correlation between lycopene and c value, for the whole data set was 0.1467, however if one looked at average mid season values the correlation with c was r^2 = 0.5598. L* value is a measure of white to dark, and as red saturation increases the color darkens, which may be indicated by the L* value. With this in mind, we also investigated the correlation between lycopene and c/L*, which was r^2 = 0.1098 for the whole data set, but for the average mid season values r^2 = 0.6142 (Figure 2). It may be beneficial to try correlating lycopene values with either chroma or chroma/L* in the future.

4. Conclusions

Lycopene content in California-grown processing tomatoes was influenced by variety, season and growing region. The range in lycopene contents from all samples evaluated was 84.1 to 172.9 mg/kg fresh weight. Mid season varieties had higher average lycopene contents than early season. During the early season, Stanislaus and Yolo county-grown tomatoes had the most lycopene, while during the mid season Fresno and San Joaquin county tomatoes were highest. Lycopene content correlated best to colorimetric measures of chroma and chroma/lightness.

References

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Tables

Table 1. Early Season Observational Varieties

Lycopene Normalized to 6 Brix (mg/kg fresh weight)				
Variety	Colusa	Stanislaus	Yolo	Average
AB 97-453	84.1	140.1	129.3	116.77
APT 723	103.3	147.7	157.7	123.39
BOS 351	87.0	124.1	110.5	101.52
Brigade	108.9	133.8	130.3	116.90
CXD 206	99.0	139.6	140.0	121.68
ENP 113	103.7	131.5	139.2	120.33
ES 911	101.9	150.1	153.2	124.46
FMX 1115N	88.7	109.6	126.2	104.37
H 8773	111.7	146.7	138.1	119.15
H 9552	117.6	155.8	165.7	138.72
H 9881	95.6	147.4	135.7	114.66
H 9888	103.3	139.6	137.5	123.99
PX 1817	87.4	113.1	125.1	107.05
PX 20816	97.5	122.7	106.2	106.74
RPT 2332	98.3	131.4	122.6	111.95
Average	99.19	135.55	134.49	

Table 2. Early Season Replicated Varieties

Lycopene Normalized to 6 Brix (mg/kg fresh weight)				
Variety	Colusa	Stanislaus	Yolo	Average
ASG 403	102.12	142.02	121.81	115.45
ASG 410	108.06	151.35	127.77	122.85
CXD 187	111.21	139.35	142.58	123.31
CXD 204	110.94	153.33	153.63	130.90
FMX 1080N	101.75	118.92	124.04	109.74
H 9280	105.59	142.72	146.69	121.68
H 9661	102.63	149.72	136.82	121.09
HyPeel 280	100.62	146.56	141.10	121.57
HyPeel 45	91.59	111.35	109.75	101.05
Red Century 32	111.61	151.14	141.02	128.02
Sun 6235	102.57	141.65	118.20	115.85
Sun 6287	98.75	147.62	148.74	123.80
Average	103.95	141.31	134.34	

Table 3. Mid Season Observational Varieties

Lycopene Normalized to 6 Brix (mg/kg fresh weight)								
Variety	Colusa	Fresno Mid	Merced	San Joaquin	Sutter	Yolo	Fresno Late	Average
AB 97-405	151.2	139.2	109.2	124.5	128.2	156.1	140.7	135.59
APTX 391	144.2	144.5	156.4	137.0	117.0	---	125.8	137.48
Brigade	121.7	157.6	149.0	134.5	130.1	154.4	134.5	140.25
CXD 161	111.7	163.4	104.5	110.0	108.7	147.4	136.6	126.05
CXD 188	146.1	130.2	129.0	122.1	105.1	97.8	136.8	123.87
CXD 203	132.7	119.8	140.0	99.9	114.1	101.1	120.7	118.31
CXD 207	116.4	122.3	108.5	112.1	101.0	122.6	141.0	117.70
CXD 208	97.3	129.4	100.0	142.5	119.8	109.7	143.3	120.28
ES 1086	150.5	123.7	141.9	160.2	114.1	117.6	---	134.67
FMX 1114N	118.9	122.3	110.3	122.6	98.3	117.0	125.0	116.33
Gibraltar 505	115.6	152.5	123.1	119.5	120.0	139.1	135.3	129.28
H 9663	123.8	152.9	142.3	133.1	108.1	110.5	145.3	130.87
H 9773	111.9	123.5	137.3	121.3	105.0	119.4	152.2	124.34
H 9775	145.5	172.9	139.4	128.4	108.2	135.7	146.8	139.54
La Rossa	117.2	---	149.3	168.2	123.9	130.8	133.4	137.11
NDM 551	136.3	123.0	129.5	125.5	108.6	117.5	98.7	119.86
OSX 388	136.6	159.4	118.6	143.5	118.9	142.6	136.2	136.54
OSX 395	112.9	121.4	120.3	138.0	95.3	118.7	115.6	117.45
PS 34716	123.6	135.5	96.9	111.8	100.3	121.8	140.0	118.56
PX 41816	136.9	129.9	138.9	131.5	125.1	108.5	127.7	128.36
Sun 6270	109.3	139.2	124.3	120.3	118.6	123.4	145.8	125.85
Sun 6321	133.8	---	162.7	171.9	101.9	157.6	137.7	144.27
Sun 6337	109.7	134.9	138.8	128.0	105.0	108.2	119.6	120.60
TA 1533	118.6	121.7	---	120.0	---	96.1	---	114.08
TA 1534	109.6	109.3	---	126.6	93.1	109.4	---	109.60
U 570	126.1	142.2	133.2	141.1	107.5	125.0	154.4	132.80
U 9411	120.7	132.0	119.5	99.8	111.3	121.8	143.2	121.16
UG 709	153.6	136.6	122.2	130.6	113.6	117.5	159.0	133.29
Average	124.53	136.68	131.01	131.06	109.66	122.41	136.93	

Table 4. Mid Season Replicated Varieties

Lycopene Normalized to 6 Brix (mg/kg fresh weight)

Variety	Colusa	Fresno Mid	Merced	San Joaquin	Sutter	Yolo	Fresno Late	Average
AB P721	124.3	133.0	114.3	134.0	99.4	115.1	132.5	121.81
APTX 539	139.0	141.1	135.0	149.4	125.5	119.1	149.1	136.88
BOS 20/20	130.8	133.7	127.2	143.1	93.6	118.2	135.1	125.97
BOS S55	119.6	127.0	122.0	125.4	98.7	105.8	124.4	117.56
CXD 179	121.3	142.8	126.1	133.3	108.4	113.9	127.7	124.76
CXD 199	136.2	151.6	128.1	134.8	129.5	---	149.0	138.19
H 8892	135.1	152.6	137.2	139.1	113.8	116.8	131.7	132.32
H 9491	148.8	150.0	139.2	148.3	119.1	125.6	144.2	139.31
H 9492	137.5	157.7	143.9	147.3	119.5	131.6	150.0	141.07
H 9553	140.3	166.3	141.6	143.5	116.3	124.5	134.0	138.09
H 9557	133.9	140.1	131.9	141.9	117.6	119.2	135.0	131.37
H 9665	132.7	143.1	126.7	133.9	111.0	103.1	128.9	125.63
Halley	116.0	126.2	122.1	126.1	101.0	100.7	---	115.32
HyPeel 303	130.9	147.1	133.0	138.2	110.7	120.5	142.3	131.82
HyPeel 513	138.8	144.3	138.9	148.7	114.8	108.0	141.9	133.62
HyPeel 65	123.6	127.0	119.8	125.1	99.1	107.1	125.6	118.18
Sun 6229	124.0	141.5	127.9	133.4	109.3	100.4	127.2	123.40
U 573	127.3	128.4	119.8	138.2	103.4	119.2	137.7	124.85
Average	131.11	141.86	129.70	137.99	110.59	114.64	136.25	

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Figures

Figure 1. Lycopene content vs. a* value for all tomato varieties and regions harvested in the early season

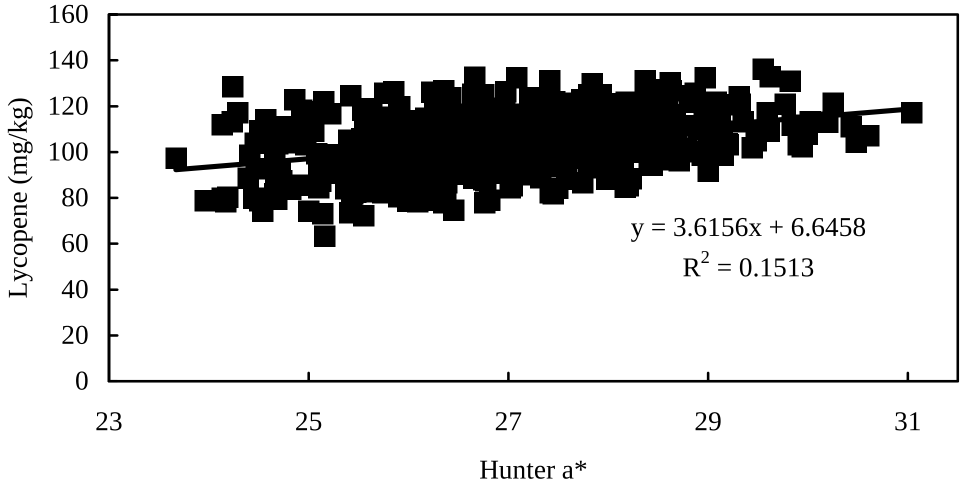

Figure 2. Lycopene content vs. chroma/L* value averaged over all growing regions for mid season varieties