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QUALITY OF FRUITS IN MEXICAN TOMATO (*Lycopersicon esculentum* Mill.) LANDRACES

CALIDAD DE FRUTOS EN VARIEDADES NATIVAS MEXICANAS DE TOMATE (*Lycopersicon esculentum* Mill.)

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ABSTRACT

Mexico is a center of domestication and diversification of tomatoes, with various landrace cultivated populations and wild varieties, but the documentation is poor in terms of their physical, chemical and nutritional characteristics. Thirteen accessions were collected and then sown and transplanted in greenhouse conditions under a randomized complete block design with four replications. This process was performed in order to evaluate the lycopene content, ascorbic acid and other physicochemical characteristics, as well as the effect of storage conditions on lycopene loss of a sample of tomato fruits native from different regions of Mexico. The analysis of variance shows significant differences ($P < 0.05$) among accessions for titratable acidity, pH, lycopene on wet and dry basis, in the CIE chromaticity coordinates L^*, a^* b^*, and in the maturity index. GTO-11, OAX-115, PH-102 and PH-96 accessions stood out for their lycopene content on wet and dry basis with values above 20 and 300 mg 100 g^{-1}, respectively. Lycopene content in samples of ground tomato fruits decreased after storing them at -20°C; it also decreased in the scalded samples immersed in boiling water.

Keywords: *Lycopersicon esculentum*, lycopene, ascorbic acid, soluble solids, postharvest.

RESUMEN

México es un centro de domesticación y diversificación del tomate con diversas poblaciones nativas cultivadas y variantes silvestres, pero poco documentadas en términos de sus características físicas, químicas y nutricionales. Con el objetivo de evaluar el contenido de licopeno, ácido ascórbico y otras características fisicoquímicas de los frutos de una muestra de tomate originaria de diferentes regiones de México, y evaluar el efecto de almacenamiento sobre la pérdida de licopeno, se hizo una colecta y posteriormente la siembra y trasplante en invernadero de trece accesiones bajo un diseño de bloques completos al azar con cuatro repeticiones. El análisis de varianza detecta diferencias significativas ($P < 0.05$) entre accesiones para acidez titulable, pH, licopeno en base húmeda y seca, en las coordenadas cromáticas CIE L^*, a^* y b^*, y en el índice de madurez. Las accesiones GTO-11, OAX-115, PH-102 y PH-96 sobresalen en contenido de licopeno en base húmeda y seca con valores mayores a 20 y 300 mg 100 g^{-1}, respectivamente. El contenido de licopeno en muestras molidas de frutos de tomate y almacenadas a -20°C, decreció a medida que se incrementó el tiempo de almacenamiento, aún en las muestras escaldadas, inmersión en agua en ebullición.

Palabras clave: *Lycopersicon esculentum*, licopeno, ácido ascórbico, sólidos solubles, poscosecha.

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INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important crops worldwide due to its production and consumption volumes. For example, in 2008, 114,116 million metric tons were harvested; and the 10 most noteworthy tomato producer nations are China, the United States, India, Turkey, Egypt, Italy, Iran, Brazil, Spain, and Mexico (1). Tomato is native from South America, but the origin of its domestication is subject of debate between Mexico and Peru because both countries are often proposed as the first domesticators (2). Due to this circumstance, Mexico still uses indigenous or local varieties and wild or semi-domesticated populations in the states of Nayarit, Jalisco, Michoacán, Veracruz, Oaxaca and Guerrero, among others (3).

Despite the diversity of cultivated and wild tomato varieties reported in Mexico and Central and South America (3), there is little or no knowledge available about the nutritional composition of these cultivated native and wild varieties. Moreover, from the nutritional point of view, the tomato is considered to be a source of minerals and different antioxidant molecules such as carotenoids, ascorbic acid, flavonoids and vitamin E (4). Lycopene is the main carotenoid found in the tomato fruit, which gives it its deep-red color; and for human health, lycopene provides antioxidant properties because it neutralizes free radicals and helps to prevent or repair cell damage.

In some *in vivo* epidemiological studies, a high correlation between lycopene consumption and reduced rates of some chronic diseases, such as cancer and coronary illnesses, has been reported. It has also been reported that lycopene can help to reduce blood cholesterol levels and prevent heart disease (5). In addition, it protects the skin against ultraviolet radiation, minimizes problems associated with arteriosclerosis, prevents cardiovascular diseases and combats eye diseases. These characteristics give tomatoes the highly desirable nutraceutical food properties for the human diet (6, 7). Also, high antioxidant content levels are highly demanded in the modern varieties by consumers.

Taking into account the importance of the antioxidant and nutritional compounds in the tomato fruit for the human health, the objective of this study consisted in evaluating the lycopene content, ascorbic acid and other physicochemical characteristics in the fruits of thirteen native tomato accessions gathered from different Mexican regions, as well as evaluating the effect of storage time on the lycopene loss.

MATERIALS AND METHODS

Plant material

Samples of cultivated and wild tomato fruits was collected in the states of Guanajuato (GTO), Mexico (MEX), Puebla (SDP), Guerrero (GUE), Hidalgo (PH), Oaxaca (OAX) and Yucatan (YUC). The origin of the genetic material and fruit characteristics per accession are showed in table 1. The seed lot for each accession was sown, and the resulting seedlings were later transplanted at the

Table 1. Accessions of tomatoes (*Lycopersicon esculentum* Mill.) included in the physical and chemical evaluation.

Accession	Origin of the genetic material	Fruit length (cm)	Predominant shape of the fruit, according to Carrillo-Rodriguez, *et al.* (8)
GTO-11†	Guanajuato, Guanajuato	6.2	Pyriform (saladette type)
GUE-18‡	Sur de Guerrero	2.5	Round (cherry type)
GUE-34†	Sur de Guerrero	2.6	Flattened with shoulders (kidney-shaped type)
GUE-79†	Chilachapa, Guerrero	3.4	Flattened with shoulders
MEX-12‡	Montecillo, Estado de México	3.6	Round
OAX-115†	San Bartolo, Tlacolula, Oaxaca	2.6	Flattened with shoulders
PH-102†	Puebla-Hidalgo	2.2	Flattened with shoulders
PH-111‡	Puebla-Hidalgo	1.8	Round
PH-95†	Puebla	2.9	Flattened with shoulders
PH-96†	Puebla	2.4	Flattened with shoulders
SDP-42†	Sur de Puebla	2.5	Flattened with shoulders
SDP-43†	Sur de Puebla	2.7	Flattened with shoulders
YUC-7†	Norte de Yucatán	6.4	Pyriform

†Populations culti.vated by farmers; ‡Wild or rural populations.

autumn-winter cycle of 2007 in a greenhouse of Instituto Tecnológico del Valle de Oaxaca (located at Ex-Hacienda de Nazareno, Xoxocotlán, Oaxaca) under a randomized complete block design with four replications. In each experimental plot, 200 to 400 g of completely red and firm ripe fruits (from the third and fifth raceme) were harvested to serve as analysis samples.

Color evaluation and fruit quality parameters

All laboratory evaluations were carried out in triplicate for each fruit sample. A MS/B-200S portable colorimeter (Hunter Lab®) was used to determine the color. The colors were recorded in the CIE L^*, a^* and b^* scale from readings in the equatorial zone of the fruit. pH assessment was performed using the AOAC 981.12 method (1990), the sample was directly measured with a PH 15 digital potentiometer (Conductronic®). In the juice and in the ground tomato or pulp samples, soluble solids were measured in degrees Brix (°Bx) with a PAL-1 manual refractometer (Atago®). Titratable acidity was determined through the AOAC 942.15 method (1990). 10 g of each sample was diluted in 50 mL of water and neutralized by titration with 0.1 N sodium hydroxide, and the results are expressed as the percentage of citric acid. A taste index (TI), a maturity index (MI) were calculated from the degrees Brix data of pulp and the acidity, according to Navez, *et al.,* 1999 (9), using the following expressions: TI = [°Brix of pulp/20*titratable acid] + titratable acidity; and MI = [°Brix of pulp/titratable acidity].

The quantification of reducing sugars was carried out through the Lane-Eynon method (923.09C) of the AOAC (10), and the amount of ascorbic acid or vitamin C was assessed through the spectrophotometric method described by Dürüst, *et al.,* 1997 (11). The analysis was performed in a mixture of 20 g of the fruit pulp sample diluted in 20 mL of an oxalic acid solution (0.4%), which was left standing in the dark for 20 minutes and then centrifuged at 3500 rpm for 25 minutes. Vitamin C concentration was determined using a UV-1601 spectrophotometer (Shimadzu®) at an absorbance of 520 nm, according to the calibration curve of a standard L-ascorbic acid of 99% purity. The results are expressed as mg 100 g^{-1} of the sample.

Extraction and evaluation of lycopene content

The fruit samples were washed and then ground to a puree in a blender, and such puree was divided into three parts. The first was analyzed fresh at harvest time, and the other portions were used for two postharvest treatments: one of them (frozen sample) was stored at -20°C in a freezer (American®); and the other was scalded (by immersing the puree in boiling water for 5 seconds) and then stored at -20°C until its analysis was performed. Lycopene loss was determined by calculating the difference between its content at harvest and the quantifications obtained at 26 different storage times from 138 to 411 days after harvest, sampled randomly.

The lycopene content was determined on wet and dry basis, and evaluated according to the method reported by Davis, *et al.,* 2003 (12). The 0.6 g ground sample was mixed with a solution of ethanol:acetone:hexane (1:1:2) by shaking it for 15 minutes in ice. Then, 3 mL of deionized water were added and the mixture was shaked again for 5 minutes. After that, it was left standing for 5 minutes at room temperature, protected from sunlight. Then, readings were made with the UV-1601 spectrophotomer (Shimadzu®) at 503 nm, taking the calibration curve of a lycopene standard of tomato at 90% purity as reference. Results were expressed in mg 100 g^{-1} of the sample.

Statistical analysis

An analysis of variance (ANOVA) was performed with the linear model of randomized complete blocks, based on the distribution in the greenhouse. Also, a multiple comparison of means was carried out by Tukey's method ($P \leq 0.05$), in order to test the differences among accessions. Subsequently, another ANOVA was performed with a bifactorial model of completely randomized blocks to determine the differences between storage conditions. Factor A was composed of two storage treatments, and factor B by 26 storage times. Finally, a simple linear regression analysis was conducted between the lycopene content loss and postharvest storage times with and without scalding.

RESULTS AND DISCUSSION

The healthy benefits of tomato consumption are mainly attributed to the content of carotenoids (such as lycopene) and vitamin C. In this study, there were significant differences ($P < 0.01$) among the accessions evaluated in relation to titratable acidity, pH and lycopene on wet and dry basis. In contrast,

the accessions were not significantly different ($P > 0.05$) in reducing sugars, soluble solids (°Brix in juice and pulp) and vitamin C. Particularly, the accessions OAX-115, PH-102 and PH-95, locally known as 'riñon' (kidney-shaped), showed the highest values in titratable acidity. A similar pattern of high values was found for OAX-115 (kidney-shaped type), PH-111 (wild cherry type), GTO-11 (saladette), and PH-96 (kidney-shaped), in relation to lycopene content on wet and/or dry basis (table 2). Results show that, in native Mexican cultivated and wild tomato populations, there is a significant variation in fruit composition that could be used in breeding programs to increase fruit quality, for example, acidity and lycopene content.

The lycopene content on a dry basis estimated in this research was greater than the content found in other studies. For example, in the Naomi F1 tomato variety, a variation that ranged from 101.9 to 175.5 mg 100 g^{-1} was reported in six harvests per year (13). And, in another study conducted in Israel with cherry and saladette tomato varieties, a variation that ranged from 51.1 to 125.0 mg on a dry basis, and 2.04 to 6.94 mg on a wet basis was found (14). While in this research, the variation ranged from 194.8 to 369.8 mg, and from 12.4 to 22.9 on dry and wet basis, respectively.

In general terms, it is difficult to generate a robust estimator of lycopene content in the different varieties or genotypes of tomato because it depends on the laboratory method used, HLPC or spectrophotometry (15); the genetic variation of the plant material (14); the influence of the variation related to light and temperature during cultivation (13, 16); the addition of fertilizer (17); and the storage conditions after the harvest (18, 19). However, a continuous evaluation of the accessions in different growing environments will allow performing an accurate estimation of the patterns of genotypic variations, since the market and consumers are demanding food with high nutraceutical values (5, 6).

There were no significant differences among accessions in ascorbic acid (vitamin C) content, but a wide variation was found (ranging from 3.7 to 17.8 mg 100 g^{-1} of the sample); more details are shown in table 2. In this case, the coefficient of variation was the highest (33.3%), indicating that the evaluation must be performed with care, or that the number of replicates should be increased to obtain a more accurate estimate, since vitamin C is easily adulterated by light and heat action.

Regarding the color of the fruits, as a measurement of the degree of maturity and as a physical characteristic associated with quality for the

Table 2. Mean values of the tomato fruit composition of thirteen accessions from different Mexican regions.

Accession	Titratable acidity	Reducing sugars	°Brix		pH	Vitamin C	Lycopene basis	
			Juice	Pulp			wet	dry
GTO-11	0.40 ab[Z]	4.04 a	5.75 a	7.26 a	4.32 b	17.8 a	22.9 a	338.0 a
GUE-18	0.45 ab	3.02 a	6.09 a	6.14 a	4.25 bc	12.1 a	12.4 c	204.1 c
GUE-34	0.60 ab	3.29 a	6.80 a	6.99 a	4.20 bc	10.6 a	18.9 abc	283.5 abc
GUE-79	0.59 ab	3.38 a	6.37 a	6.61 a	4.08 bc	7.6 a	13.3 c	204.2 c
MEX-12	0.48 ab	4.05 a	6.10 a	6.97 a	4.14 bc	12.3 a	13.8 c	194.8 c
OAX-115	0.62 a	4.00 a	7.12 a	7.72 a	4.15 bc	12.4 a	22.6 a	308.7 abc
PH-102	0.72 a	3.09 a	7.58 a	7.52 a	4.14 bc	9.6 a	21.1 a	315.8 ab
PH-111	0.43 ab	3.33 a	7.97 a	7.88 a	4.75 a	11.2 a	14.7 bc	219.6 bc
PH-95	0.62 a	3.10 a	8.01 a	6.66 a	4.01 b	9.2 a	19.1 ab	265.3 abc
PH-96	0.57 ab	3.67 a	7.87 a	7.60 a	3.96 c	10.2 a	21.8 a	369.8 a
SDP-42	0.47 ab	3.29 a	6.31 a	7.11 a	4.08 bc	3.7 a	13.7 c	228.9 bc
SDP-43	0.52 ab	3.33 a	6.48 a	6.63 a	4.08 bc	4.8 a	15.8 bc	259.4 abc
YUC-7	0.30 b	2.75 a	4.38 a	5.18 a	4.29 bc	5.4 a	16.5 abc	360.1 a
Value of F	2.97**	1.02ns	1.39ns	0.96ns	5.21**	1,44ns	2.67**	2.30*
CV (%)	14.19	0.42	22.07	10.90	0.60	33.30	5.30	0.50

[Z]Means with the same letter in a column are not significantly different according to Tukey's test ($P \leq 0.05$); ns, *, **, not significant and significant at $P > 0.05$, $P \leq 0.05$ and $P \leq 0.01$, respectively. CV, coefficient of variation.

consumer, it was determined that the significantly highest values for factor L^* (lightness or reflectance of light) corresponded to the following types: saladette GTO-11 and YUC-7, flattened with shoulders GUE-79 and OAX-115, and cherry PH-111 (table 3). The external appearance of the fruit is an important factor for the consumer.

No significant differences were found among accessions for the taste index, but significant differences were found for the maturity index. Once again, the PH-111 accession showed the highest value in the maturity index, which confirms this accession as a promising material on the fruit color basis (high values of L^* and a^*). PH-111 was followed by GTO-11, YUC-7 and SDP-42 with values above 15 in the maturity index (table 3).

Different studies have shown that lycopene is lost when the fruit is dried or processed, due to the warming-up of the sample (20) or the storing process in the dark at 4, 7, 25 and 35°C (18, 21), among other reasons. The variation differs according to the variety. In this research, an inconsistent increase of the loss of lycopene was found (wet and dry basis) between 130 to 411 days after harvest in pulp samples stored at -20°C. In the analysis of variance, significant differences were identified between the two post-harvest treatments evaluated (wet basis; $F = 6.52$; $P \leq 0.01$; dry basis; $F = 5.75$; $P \leq 0.01$) in samples with and without scalding, both stored at -20°C.

The lycopene content at harvest time was 17.4 and 273.2 mg 100 g^{-1} on wet and dry basis, respectively. After the scalding treatment, the lycopene content decreased to 10.4 and 164 mg 100 g^{-1}; and for the samples without scalding the content was 8.6 and 135.1 mg 100 g^{-1} on wet and dry basis, respectively. That is, the loss of lycopene was evident in both post-harvest treatments, but it was less drastic when the sample was immersed in hot water and later stored at -20°C (scalding treatment). Results indicate that the lycopene loss always occurs in the fruits after being harvested and stored, as it has been shown in other studies. For example, lycopene loss occurs in fruits stored at room temperature (18, 21) and in boiled, baked, or fried fruits (22). Hence, it is always preferable to eat recently-harvested fresh tomatoes in order to take the maximum advantage of their nutritional and antioxidant properties.

The average rate of lycopene loss on wet and dry basis was 0.31 and 4.5 mg 100 g^{-1}, respectively, between the 138 and 411 days after storage at -20°C, with and without scalding as it is shown on figure 1. These results indicate that fresh tomato juice and pulp do not retain their chemical characteristics under high freezing temperatures,

Table 3. Average colorimeter readings for color, and taste and maturity indices of thirteen tomato accessions.

Accessions	CIE LAB chromaticity coordinates			Taste index	Maturity index
	L^*	a^*	b^*		
GTO-11	38.6 a[z]	31.4 a	24.9 a	1.30 a	17.96 ab
GUE-18	37.5 ab	24.8 abc	13.2 c	1.13 a	13.30 ab
GUE-34	36.7 ab	25.2 abc	13.4 c	1.19 a	11.82 b
GUE-79	38.2 a	26.6 abc	21.8 abc	1.16 a	11.46 b
MEX-12	37.0 ab	24.3 abc	22.8 abc	1.21 a	14.58 ab
OAX-115	40.0 a	32.1 a	18.7 abc	1.28 a	13.16 ab
PH-102	37.6 ab	29.8 a	20.5 abc	1.24 a	10.55 b
PH-111	40.7 a	30.9 a	23.4 ab	1.37 a	18.80 a
PH-95	36.5 ab	25.6 abc	20.7 abc	1.17 a	10.97 b
PH-96	37.7 ab	26.3 abc	16.0 bc	1.28 a	14.17 ab
SDP-42	37.1 ab	22.6 bc	13.6 c	1.27 a	15.99 ab
SDP-43	37.1 ab	21.8 c	13.6 c	1.13 a	11.71 b
YUC-7	39.9 a	31.4 a	27.4 a	1.17 a	17.31 ab
Value of F	2.34★	6.66**	7.45**	0.86[ns]	2.05*
CV (%)	4.22	8.59	16.02	11.77	24.02

[z]Means with the same letter are not significantly different according to Tukey's test ($P < 0.05$); [ns], *, **, not significant and significant at $P > 0.05$, $P \leq 0.05$ and $P \leq 0.01$, respectively. CV, coefficient of variation.

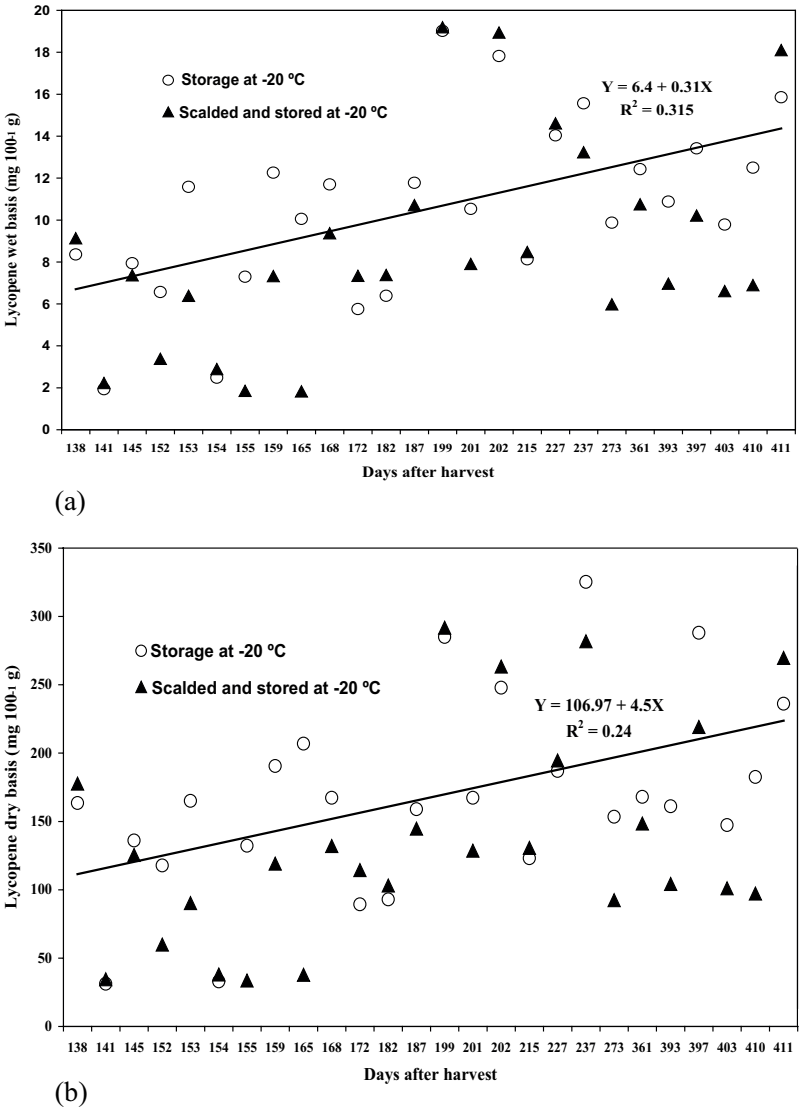

Figure 1. Relationship between lycopene loss on wet basis (a) and dry basis (b), and the days after harvest under two postharvest treatments and storage at -20ºC.

as it was described here for the -20ºC test, since the metabolic processes of maturation are not stopped. Therefore, soluble solids, titratable acidity and pH also decrease over time, even in controlled atmosphere conditions with different oxygen levels and a temperature of 12ºC (23).

CONCLUSIONS

The physical and chemical analysis of the fruits of thirteen tomato accessions showed significant differences in titratable acidity, pH, lycopene (on dry and wet basis) in the CIE chromaticity coordinates L^*, a^* and b^* that determine the color of the ripe fruit, and in the maturity index. GTO-11, OAX-115, PH-102 and PH-96 accessions stood out for their lycopene content on wet and dry basis with values above 20 and 300 mg 100 g^{-1}, respectively. The lycopene content in ground tomato fruit samples decreased after being stored at -20°C, even when a post-harvest scalding treatment was performed. However, the lycopene loss in the scalded samples was less drastic than in the samples that were not scalded, with average rates of 0.31 and 4.5 mg 100 g^{-1} per day, on wet and dry basis, respectively.

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