Tomato Fruit (*Lycopersicum esculentum* Mill) Maturity Study Based on Sensorial Analysis and Instrumented Color Determination

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Abstract. Table tomatoes (*Lycopersicum esculentum* Mill) have been tested during maturation process by carrying color determination by means of instruments as well as trough sensorial analysis, aiming to stablish data correlation between both methods. Recent picked testing fruits were selected by taking into account an uniform physiological maturation considered adequate for harvesting. Fruits were presented to a group of trained volunteers and employing a non-structured scale. Instrumental readings were carried by means of a "Macbeth" HUNTERLab equipment at five points selected on the transversal fruit axis. Sensorial color determination did not present significant difference ($p \leq 0.05$) between the days 1, 3 and 5; 5 and 8; 10 and 12; and 12, 15, 17 and 19, however differences were noted between these groups. The fruits showed moderated characteristic colors between the 10th and 12th day and very characteristic colors from the 12th.

Keywords: Tomato fruits, fruit color, fruit maturation, sensorial analysis, instrumental color determination.

1 Introduction

Tomato is considered the horticultural crop of major worldwide commercial interest. As reported by the FAO (2014), world consumption of tomato in natura guarantees the second place of importance. Tomato is cultivated in different zones of Brazil, in all the seasons as well as in a variety of crop handling systems. These details promote a high production, placing the country among the bigest tomato producers in the world, as China, USA, Italy, Turkey, Spain, Egypt and Mexico (Cardoso et al 2010). The total área devolted to tomato crop in Brazil reaches 66.418 hectares which produces 4,146,466 metric tons a year, yielding 62.616 kg/ha. IBGE (2012).

Tomato is a climacteric and perishable fruit which requires adequate storage conditions in order to delay ripening process, to minimize losses as well as to increase shelf life (Brackmann et al., 2007). Only fruits meeting expected qualities by the consumers will be considered for commercialization. Color is an important

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quality attribute which is close associated to maturity and together with shape, size, firmness, bruising and defects will support consumer selection.

Fruit color perception is associated to some characteristics as the combination of certain pigments. Small changes of fruit color are connected to certain factors as maturity, exposition to radiant energy, size, burning, tanning, etc Little (1973).

As reported by Nickerson, apud Lozano (1977), color can be determined through an appropriate system based on tonality, luminosity and on the chromaticity of our sensations. Instead of describing them, MUNSELL developed a system which stablished the three color dimensions and measuring each one of them by referring to an appropriate scale.

As reported by Setser (1984), due to variation, the surface characteristics have to be standardized before submission to color determining instrument. In case of non-homogeneous distribution, the readings should be repeated in order to increase the data reliability. Hobson et al (1983) reported an objective method to define composition changes during maturation process by setting tomato fruits in a varying degree of maturation. Initially, the authors restricted the test to a cultivar and used a spectrophotometer of the HUNTER Lab system. Color has been measured during fruit maturation after carrying sensorial analysis in a color sequence. The authors conclusions referred to the applicability of the proposed method to other cultivars in a varying maturation levels.

Thai, Shewfelt (1991) presente a physical analysis of tomato color by means of an HUNTER Lab SYSTEM spectrophotometer calibrated with a rose pattern model. Eight spaced readings have been carried out around the fruit equator and recorded in software. The resulting mathematical model involving “C” (chromaticity) and “H” (tonality) which hae been statistically analyzed. The authors verified that “L”, “H” and “C” were correlated to sensorial color perception.

Borguini, R. G.; Silva, M.V. in 2005 determined texture, other physical properties and color of Debora and Carmem tomato cultivars produced under organic as well as under conventional agricultural practices. Sensorial analysis of these samples indicated no difference for red tonality between both agricultural practices. Instrumental color readings adopted the mathematical model for C (chromaticity) and h (tonality). It was observed that L,h and C yielded good correlation for subjective color.

Thai, Shewfelt (1991) reported an experimental evaluation of tomato color based on the Shewfelt et al (1987) method adapted to red tomatoes. Volunteers were trained to designate grades in a non-structured scale on a line of 150 mm of length, showing an initial mark de 0 to 12, where 0 indicates no-red color, next to 75 mm indicating light red color and 138 mm indicating total red color.

Borguini, R. G.; Silva, M.V. (2005) comments that the “h” parameter defined the basic sample color and also represented the average sample tonality. The authors also verified that as great as the color angle “h” it means that fruit color was close to the yellow and as the small the angle the close to red was the color. It was also noted non-significant difference of red color when compared the fruits produced by both agricultural practices. Tomato shelf life is influenced by the maturation level at which the fruits were harvested and stored.

2 Materials and Methods

2.1 Materials

In the experimental part of this research work the tests were carried with table tomato Santa Clara cultivar I 5300. The choice of that cultivar was based on the productivity reached in the area of Campinas, SP, Brazil. Tomatoes were direct picked on the field during morning period. Physiological maturity level, uniformity, free of bruising, as stated by the IFT (1981).

Difuse Reflectance Spectophotometer. Tomato color analysis carried during the storage period was tested by a MACBET 1500 plus model in the Laboratory of the Chemistry Institute at The State University of Campinas, SP, Brazil, where all the instrumental fruit color determination were carried out. Spectophotometer readings were transmitted to a software available in the instrument, where they were codified and stored.

During reflectance measurement by the Hunter Spectrophotometer, the incident light beam was reflected as a diffuse beam which was collected and measured by the sphere as is displayed. The spectrophotometer emits a light beam which does not inside perpendicularly onto the sample surface.

The spectrophotometer was developed by HUNTER in 1950 based on the Hering Opponent-Process Theory. Color determination refers to red and green as well as between yellow and blue. Three dimensional view representing the color determination results, where 1) the dimension +a and –a refers to the chromaticity red-green, 2) the dimension +b – b refers to the chromaticity yellow – blue, meanwhile the dimension L measures luminosity.

Sample chromaticity was obtained through the equation:

$$C = (a^2 + b^2)^{1/2} \quad (1)$$

which represents the hypotenuse of the rectangle triangle having “a” and “b” as sides, as shown on Fig. 2. Tonality was obtained through the angle “H” obtained by

$$H = tg^{-1}(a/b) \quad (2)$$

The fruit total color variation is given by:

$$(\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2} \quad (3)$$

Where ΔL, Δa and Δb stands for the reading differences between the first and the second day of observation, as reported by Little (1982). Where c= chromaticity, -a to +a = green to red color, -b to +b = blue to yellow color and H = tonality.

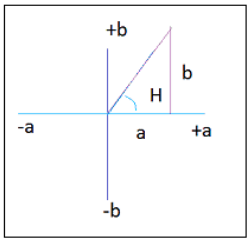


Fig. 2. Scheme for three dimensional color measurement.

2.2 Methods

Preliminary analyzis - Commercial classification. The commercial tomato classification directed to "in natura" consume for the domestic market was based on the Brazilian Program for the Horticulture Modernization – Tomato Classification Norms, Horticulture Quality Center, CQH/CEAGESP.

Preliminary analyzis - Physical properties. Fruit dimensions were surveyed by means of a caliper, by selecting a number of 24 individuals at random, taking into consideration the fruit shape. Specific weight determination was based on the Archimedes Principal as recommended by Mohsenin, N. N. (1965). The fruit was placed in a 1000 ml beaker together with 500 ml of water avoiding contact between fruit and the glass sides. The displaced water volume was calculated by means of equation (4).

$$P_r=(P_f.D_{H2O}/P_d) \quad (4)$$

Where "P_f" – fruit weigth in grams - "D_{H2O}" stands for water density given in g/cm3 - "P_r" is the real specific weight in g/ml.

In order to determine the apparent weight it was employed a container with the dimensions of 31x18x11 cm having a volume of 6138 cm3 which was filled with the fruits in a natural way, i.e., without interference, without excess or missing fruit. Tomato weight was calculated by the difference between the total weight and the container weight, as indicated by the equation (5) as recommended by Mohsenin, N. N. (1965), as

$$P_{ap}=(m/V_r) \quad (5)$$

Where “m” is the product mass in g, “P_{ap}” is the aparente specific weight in g/ml, “V_r” is the container volume in ml.

After determining the real and apparent weight, the porosity was obtained by equation (6) from Mohsenin, N. N. (1965).

$$P=(1-P_{ap}/P_r)x100 \quad (\mathbf{6})$$

Where “P” is the porosity in %, “P_{ap}” is the apparent specific weight in g/ml and “Pr” is the real specific weight in g/ml.

Preliminary analyzis - Sensorial analysis judges selection. Judges training took place in the three weeks preceding the experimental phase. Initially 30 individuals including men and woman have been invited as volunteer judges. Individual’s acuity have been evaluated following FARNSWORTH MUSELL – 100 - HUE (1957) recommendation for color description. Following that preliminary test, 23 individuals having normal vision for color were selected. In the next step individuals were selected for discriminative ability for color, judgment reliability and consensus with the remaining individuals. Significant differences were noted between individuals.

A non-structured scale of 9 cm of length based on the IFT (1981) was anchored at the ends ranging from “nothing” (for totally green fruit) to “well characterized” (for totally intense red tomato). During the test the judge is supposed to mark the identified color on the line.

Selection tests have been set by including 05 fruits for each judge with three replications each, from which the F test was carried for the Analysis of Variance, where P varying from ($F_{\mathbf{calculated}} \leq 0{,}30$) $\geq 0{,}05$ is the probability of acceptance of the difference between judges, concluding that significant difference between judges did not occur. Based on that, nine judges have been selected, (Banzatto e Kronka, 1989).

Experimental analyzis. - Sensorial analyzis for color. A set of 20 tomatoes a day randomly selected from the initial group was used as recommended by Gormley, Keppel (1976) and presented to nine judges previously selected. Each judge carried individual evaluation of the samples checking his perception on the scale as explained before.

Color tests were carried out under the day ilumination which Windows were facing the north direction and iluminated with fluoresecent light as recommended by FARNSWORTH MUSELL 100 HUE (1957).

Experimental analyzis. - Color Instrumental Analysis. Following, after the sensorial tests the 20 individuals were analyzed through the diffuse reflectance spectrophotometer, using an observation angle of 100, in the CRIIS configuration, D illuminant and L,a,b patterns. A number of five readings were carried out on each fruit surface. The HUNTER Lab, system was used as recommended by Litle (1982).

Experimental analyzis. - Statistical analyzis. The statistical analysis was carried primarily to verify the differences between the parameters under consideration, i.e., L, a, b, c, DE as well as the sensorial analysis through the analysis of variance and Tuckey test at 5%. (Banzatto and Kronka, 1989).

3 Results and Discussion

3.1 Commercial Classification

Lycopersicum esculentum Mill, Santa Clara I 5300 cultivar exhibits an outstanding productivity and used for "in natura" consumption. Cultivar characteristics included oblong and bilocular fruit, indeterminate growing plant with 110 days (summer) of productive cycle, cultivated with anf average number of twenty thousand plants per hectare. Seeds germinate in 5 days and harvesting takes place in 100 to 110 days after seeding. That variety is tolerant to *Fusarium oxysporum* 1 e 2, *Verticillium dahliai*, *Verticillium abloatrum* and *Stemphylum*.

Fruits were harvested at the physiologically developing point showing uniform green color, homogeneous size and free of bruising, being classified as:

- Group "I" – Fruits present the longitudinal diameter larger than the transversal one.
- Class "big" – Fruits present a minimum diameter of 62 mm.
- Type "Extra" – The summation of defects did not exceed 7% of the total number of analyzed fruits.

3.2 Physical Properties

Table 1. Presents the average values of Real Specific Weight, Aparent Specific Weight, porosity, Size as well the respective standard deviation of the fruits included in the analysis.

	real specific weight(g/cm^3)	apparent specific weight (g/cm^3)	porosity (%)	size average values (cm) obliqúe	real specific weight (g/cm^3) distance
Average	0.957	0.550	43.60	6.61	6.81

3.3 Instrumental and Sensorial Analysis.

Table 02 presents average values of the sensorial and instrumental determinations for the color parameter during the maturation period. Table 03 displays the analysis of variance results.

Table 2. Sensorial and color analysis daily average results of 20 fruits.

Day	sensorial color	color "a"	color "c"	color "H"	color "L"	color "b"	color "ΔE"
1	1.5	-5.11	21.97	103.52	49.46	21.33	54.11
3	1.33	-4.54	21.41	102.17	49.13	20.73	53.51
5	2.03	2.98	21.56	96.72	47.16	21.02	51.72
8	3.86	6.06	23.23	76.1	42.29	21.24	50.39
10	5.5	7.98	23.76	67.38	42.02	20.94	47.62
12	6.67	15.11	25.71	53.1	40.22	19.74	47.28
15	7.54	16.24	23.97	45.4	38.09	17.73	45.04
17	7.85	17.96	25.41	45	37.75	17.88	45.47
19	8.22	20.03	26.09	40.33	36.74	17.59	45.39

Table 3. Analysis of Variance (ANOVA) results for the variables considered during the fruit maturation period.

	P>F	**C.V.**	**R^2**	**average**
Sensorial color	0.0001	40.42	0.63	5.05
Color "a"	0.0001	57.11	0.83	7.83
Color "c"	0.0001	9.66	0.37	23.66
Color "H"	0.0001	16.82	0.82	70.34
Color "ΔE"	0.0063	121.33	0.12	11.78
Color "L"	0.0001	13.62	0.39	41.94
Color "b"	0.0151	18.2	0.11	19.34

C.V. – Coefficient of variation; P>F – level of significance; R2 – Coefficient of correlation. data univariate analysis (ANOVA)

The ANOVA for color indicates the occurrence of differences between the samples at $p \leq 0.05$. Tukey test was carried for multiple comparisons between the averages. The values exhibiting the same letters do not present significant difference between them at 5% of significance.

Table 3. Tukey test results are presented on Table 03 for each studied parameter during the maturation period

Days	color			
19	8.22	a		
17	7.85	a		initial level
15	7.54	a		
12	6.67	a	b	intermediate level I
10	5.55		b	
8	3.86		c	intermediate level II
5	2.03		c	d
1	1.50			d final level
3	1.33			d

Sensorial color determination did not present significant difference ($p \leq 0.05$) between the days 1, 3 and 5; 5 and 8; 10 and 12; and 12, 15, 17 and 19, however differences were noted between these groups. The fruits showed moderated characteristic colors between the 10th and 12th day and very characteristic colors from the 12th.

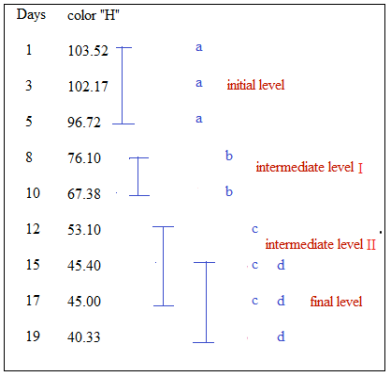
Table 4. Tukey test results for color "a" during the maturation period.

Days	color "a"			
19	20.03	a		final level
17	17.96	a	b	
15	16.24	a	b	intermediate level I
12	15.11		b	
10	7.98		c	intermediate level II
8	6.06		c	
5	-2.98			d
1	-4.54			d initial level
3	-5.11			d

The fruits included in the same maturation level did not show significant ($p \leq 0.05$) for the parameter "a", i.e., green – red color. Encountered maturation levels were composed of the days 19, 17 and 15; 17, 15 and 12; 10 and 8; 5, 3 and 1, however significant difference ($p \leq 0.05$) between the groups did occur, but with some similarities between the last two groups.

Parameter "c" for color, reveals the chromaticity of the tomato samples during maturation. Significant difference ($p \leq 0.05$) was not noted between the days 19, 17, 15, 12 and 10; 17, 15, 10 and 8; 10, 8, 5, 3 and 1. These results also show some similarities between the three maturation levels with increasing chromaticity from the 17th maturation day on.

Table 5. Tukey test results for color "H" during maturation period



The "H" parameter for color characterizes the fruit tonality during the maturation period and significant difference ($p \leq 0.05$) between the days 1, 3 and 5; 8 and 10; 12, 15 and 17 and 15, 17 and 19 were noted, but differences occurred between these groups. These results reveal four levels of tonality decrease during maturation period. The two last maturation levels presented some chromaticity similarities in the transition and lower chromaticity from the 17th of maturation.

The "ΔE" parameter represents the total fruit color variation during the maturation period. Tukey test results for color "L" during maturation period. No significant differences ($p \leq 0.05$) were noted during the maturation, excepting in the 8th and in the last five days of maturation. It means that the parameter under consideration cannot be taken into account as an important parameter.

Parameter "L" reveals fruit luminosity during the maturation period. Luminosity did not present significant difference ($p \leq 0.05$) between the days of 1, 3, 5 and 8; 5, 8 and 10; 8,10 and 12; and 10, 12, 15, 17 and 19.

Results indicate that fruit luminosity did not show any differences in the five first days. After the 10th day of maturation significant differences between fruits reffering to luminosity.

Three luminosity levels have been noted, in which the most intense occurred in the first day of maturation. Luminosity exhibits decaying and not well differentiable levels.

As reported by Borguini, R. G.; Silva, M.V. (2005), according to the above presented classification, as the fruit presents a higher chroma which occurs after the 15th maturation day, the analyzed fruits were noted to be in the initial chromaticity level and no differences were found between the Carmen and Debora cultivars. Raffo et al. evaluated cereja tomato type, Maomi F1 cultivar growing in green houses in Italy, obtaining a chroma value of 15.6.

4 Conclusions

Based on what it has been exposed before it can be concluded that it was possible to determine the parameter color for tomatoes of " Santa Clara" I5000 variety by means of sensorial, as well as instrumented analysis. Both methods generated reliable results as well as a statistically interpreted maturation level. The chromaticity between red and green colors, i.e. the color "a" and the color "H', i.e. the tonality, are the parameters which present the best well defined color as function maturation time.

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