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Critical points of industrial tomato from field to processing

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ABSTRACT

The authors evaluated critical points of production stages of the industrial tomato, through physical and physico-chemical analyzes of U2006 hybrid fruits in the harvest, 2016. Fruits were evaluated in relation to raw material, temperature, fresh mass, pH, soluble solids (°Brix), firmness, titratable acidity and extravasation of electrolytes. Samples were collected in six steps: manual, mechanized, truck, arrival at industry, unloading and selection mat in two periods, morning and afternoon, totalizing 60 fruits for each step, and four replications. Fruits which waited for more than 10 hours in the yard generated an increase in serious defects (%), loss of fresh mass, discount on the amount paid for the load. The most critical stages of the production process were identified when tomatoes arrived at the industry and their unloading, when the fruits presented fresh mass loss due to the high temperature. In addition, the authors highlight that a better organization in the arrivals at the industry as well as an efficient communication of crop restriction is crucial, since unscheduled stops increase waiting time, causing significant quality losses.

Keywords: *Solanum lycopersicum*, postharvest, quality.

RESUMO

Pontos críticos ocorridos em frutos de tomate industrial do campo ao processamento

Foram avaliados os pontos críticos ocorridos nas etapas de produção do tomate industrial, por meio de análises físicas e físico-químicas dos frutos do híbrido U2006 na safra ocorrida em 2016. Os frutos foram avaliados quanto à classificação de matéria-prima, temperatura, massa de matéria fresca, pH, sólidos solúveis (°Bríx), firmeza, acidez titulável e extravasamento de eletrólitos. As coletas foram realizadas em seis etapas: manual, mecanizada, caminhão, chegada à indústria, descarregamento e esteira de seleção, em dois períodos: manhã e tarde, totalizando 60 frutos por cada etapa em quatro repetições. Os frutos que esperaram acima de 10 horas no pátio geraram aumento de defeitos graves (%), perda da massa de matéria fresca, desconto no valor pago pela carga, com alterações na qualidade. As etapas mais críticas do processo produtivo foram identificadas na chegada à indústria e seu descarregamento, onde os frutos apresentaram perda de massa de matéria fresca devida à elevada temperatura. Sugere-se melhor organização nas chegadas à indústria bem como eficiente comunicação de restrição das colheitas, uma vez que paradas não programadas elevam o tempo de espera, provocando, portanto, perdas significativas na qualidade.

Palavras-chave: *Solanum lycopersicum*, pós-colheita, qualidade.

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Tomato is the second most grown vegetable consumed worldwide. This plant is a crop of great economic and social importance being also important in human diet. Goiás (86%) followed by São Paulo (12.7%) and Minas Gerais (1.3%) are the main states where tomatoes are produced for processing industries (Vilela *et al.*, 2012).

This study was carried out in the municipality of Morrinhos, Goiás State, where industrial tomato cultivation stands out, productivity of 112 thousand tons (IBGE, 2015).

Water content ranges from 90 to 95%, which characterizes tomato as a highly perishable fruit, with losses of up to 21% after harvest (Rocha *et al.*, 2009; Rinaldi *et al.*, 2011). According to Mendes *et al.* (2011), an increase in breathing occurs due to the production of ethylene and other biochemical reactions responsible for changes in color, texture and nutritional quality after physical damage during harvest or shipping.

Therefore, tomato maturation during harvest and pre and post harvest control are essential in order to ensure fruit quality (Beckles, 2012), preventing the entry of pathogenic microorganisms (Ronchi *et al.*, 2010). Physical damage significantly affects chemical and physical compositions of pericarp and locular tissue in tomato fruits (Ferreira *et al.*, 2009). Thus, harvest done during the appropriate maturation stage will determine fruit quality (Damatto Junior *et al.*, 2010).

We aimed to highlight the critical points from harvest to the processing of tomato fruits, being verified through physical and physico-chemical analyzes in the fruits.

MATERIAL AND METHODS

To build a data bank in this study, industrial tomato samples were obtained in concentrated maturation stage, firm fruits in properties **A** (17°50’27”S, 49°10’60”W, altitude 888 m), **B** (17°43’51”S, 49°03’46”W, altitude 821 m), and a factory specialized in tomato derivatives (17°46’13”S, 49°07’40”O, altitude 800 m), in the municipality of Morrinhos, Goiás State, Brazil. Samples were collected in six steps and in two distinct periods of the day, morning and afternoon, to observe physiological changes caused by thermal stress.

The steps were: 1) Manual harvest (in the same area, right before mechanized harvest); 2) Mechanized harvest (sample collected on selection mat, when tomatoes were harvested); 3) Samples in the truck (collected in the truck still in the field); 4) Arrival at industry (samples collected at the moment when the truck arrived at the industry); 5) Unloading (samples collected when the tomato was unloaded for processing); 6) Selection mat (samples collected on the mat, in the industry). All used samples were obtained from the same truck in all steps.

Collecting phase totalized 60 fruits per each step. Fruits were packed in plastic boxes, in four replications. After collecting, samples were taken to the laboratory in boxes, which were stored at a climate-controlled room, for up to 12 hours, at 20°C temperature.

The authors evaluated the commercial tomato hybrid U2006 for industrial processing (Nunhems Brasil-Bayer Crop Science), resistant to diseases like bacterial spot and begomovirose, considered the main phytosanitary issues of tomato for industrial processing (Villas-Bôas *et al*., 2007; Fernandes, 2008).

Fruits were collected in two properties, in the beginning of harvest, 2016. The first property where the samples were collected, named "Property A", is located 12 km away from the industry, being 10 km asphalt road and 2 km dirt road. The second property, named "Property B", located 11.2 km away from the industry, being 10.9 km asphalt road and 0.30 km dirt road.

Raw material was classified at the industry, in order to evaluate defects in fruits, which interfere with the quality required for cargo pricing. All trucks were accompanied from the field up to processing and they were classified and analyzed using industry methodologies in six defects, being four defects classified as serious defects (disintegrated, visible locules, moldy and green) and two general defects (discolored and smashed). Obtained data were recorded on the form of quality control of goods receipt. According to Table 1, adapted from ordinance n° 278, 1988, MAPA. A discount was applied on cargo weight for payment purposes.

Analyses were done at Laboratório do Instituto Federal Goiano, Campus Morrinhos, for fresh mass, pH, soluble solids, firmness, titratable acidity and extravasation of electrolytes.

Data on average temperature and relative humidity were collected on harvest days of samples in the weather station of Instituto Federal Goiano Campus Morrinhos (17°48'50"S, 49°12'16" W, altitude 902 m)

Fresh mass was measured on 30 fruits, randomly separated and put on plastic trays, being weighed in a semi-analytical balance (FCB 3K0.1, Kern, Kern & Sohn Gmbh, Stuttgart, Germany).

Titratable acidity was determined using the official method described by Instituto Adolfo Lutz, based on neutralization titration with NaOH (0.1 N) up to pH 8.2. Fruits were washed and dried with paper towels, before extraction of juice from 5 fruits per replicate using a fruit centrifuge (FastFruitInox, Suggar). Then, 1 mL of juice was transferred to an Erlenmeyer flask containing 9 mL distilled water and 3 to 5 drops of phenolphthalein indicator. Afterwards, titration was done with NaOH solution in six collect steps, in four replicates.

Acidity (in molar solution, % v/m) was calculated according to the following formula (Instituto Adolfo Lutz, 2008):

$$Ac(\%) = \frac{V*f*100}{P*c}$$

Where V= volume in mL of NaOH solution (0.1 N) spent via titration; f= factor of NaOH (0.1 N); P= mass (g) of the sample used in titration; c= correction factor used was 10, since titration was done with NaOH (0.1N).

Firmness analysis was determined using flattening technique, 0.264 kg, with the aid of a caliper (1.0004, ZAAS), measuring length and diameter (in mm) on both sides of the fruit, in five fruits and six collect steps, with four replicates. The flattened area was estimated using the ellipse area formula (A) (Calbo & Nery, 1995):

$$A = 0.784 * d1 * d2$$

In which, to convert mm to cm, the authors divided mm by 10.

A= flattened area in cm^2; d1= length (cm); d2 = width (cm).

Firmness was obtained by dividing the weight of the probe (P) kilogram force by flattened area (A) cm^2, Fz= P/A. (Calbo & Nery, 1995).

$$Fz = \frac{P}{A} * 9.8$$

In which: Fz= firmness (N); P= flattener weight; A= area in cm^2.

In order to convert fimness from Kgf to N, the equation was multiplied by 9.8.

To determine soluble solids, we calibrated the refractometer with distilled water having a zero-index of refraction. Juice was extracted from five fruits, using replication method, adding two drops of juice on the prism of the portable refractometer 0-32°Brix (RZT, Bel Engineering, Bel Equipamentos Analíticos LTDA) and then refractive index reading was carried out. After each reading, prism was properly washed with distilled water and dried with double-sided absorbent paper, until having all readings totaled (six collecting steps), performing four replicates and recording all obtained data, according to the methodology proposed by Instituto Adolfo Lutz.

To determine pH, fruits were washed and, right after, dried using a towel paper, then juice was extracted from 5 fruits of each replicate in the centrifuge (FastFruitInox, Suggar). Afterwards, they were measured using a pH meter (mPA-210, MS Tecnopon, MS Tecnopon Instrumentação) with standard solutions 4.00 and 7.00. After measurement, electrode was cleaned with distilled water and dried with double-sided absorbent paper. Thereafter, the authors performed the reading of the six-step-collection samples with four replicates, recorded the obtained data, according to the methodology proposed by Instituto Adolfo Lutz.

Membrane electrolyte extravasation was evaluated according to some adaptations from the methodology described by Vasquez-Tello *et al.*

(1990) and Pimentel *et al.* (2002). Disks in 10 fruits, 5 mm diameter, of each replicate, were collected. The disks were washed previously in water and then submerged in 30 mL distilled water, in amber bottles, for 24 hours, at room temperature. Then, free conductivity was measured (CL, μS/cm), using a benchtop conductivity meter (EC-125, HANNA, Hanna Instruments, Padova, Itália). Afterwards, the same bottles were placed in an oven (Q317M, Quimis, Quimis Aparelhos Científicos, São Roque, São Paulo) for one hour at 100°C and after cooling at room temperature, and total conductivity was measured (CT, μS/cm). In order to avoid errors, the sensor was cleaned between each reading with distilled water. The electrolyte extravasation rate was obtained using the formula:

$$\% = \frac{CL}{CT} x\ 100$$

The obtained data were submitted to ANOVA test for variance analysis and the averages were submitted to Tukey test, at 5% significance level.

RESULTS AND DISCUSSION

The morning shift waiting times were shorter, in relation to the afternoon shift, due to arrival order and process in industry.

Thus, over 10 hours of standby time, incidence of serious defects were greater than 20% (Table 2), resulting in a discount which reflected directly on the amount of money paid for the cargo, besides impacting on fruit quality. For producer and for industry, these factors are prejudicial since fruit was weighed after the waiting time in the outside area.

In Brazil, besides high luminosity, the temperatures are excellent for growing tomato, ranging from 21-28°C during the day and 15-20°C during the night (Filgueira, 2008). Average temperatures found are within the tolerance range in the morning, but not in the afternoon. Temperature in properties A and B (Table 2) showed significant differences during this period. The authors noticed some changes in the morning shift, in both properties where the weather was warmer due to the sunset and cooler during unloading due to the cold water used in this process. In the afternoon, the temperature in the field is very high and tends to decrease along harvest steps, until unloading and milling, due to the use of cold water in the last steps.

Property A did not show any significant difference in the morning (2,267 kg) and in the afternoon (2,167 kg) for fresh mass. On the other hand, property B showed significant difference both in the morning (2,389 kg) and in the afternoon (2,178 kg). The critical point was in unloading step in property A, whereas in property B, the highest loss of fresh mass was verified in

Table 1. Classification of tomato for processing adopted in industry. Morrinhos, IFGoiano, 2016.

Serious defects (%)	Discount (%)
≤ 20	Standard
20.1 a 25.0	-5
25.1 a 30.0	-10
30.1 a 35.0	-20
35.1 a 40.0	-30
≥ 40	Disapproved

Source: adapted from ordinance n°278, 1988, Ministry of agriculture, livestock and food supply.

Table 2. Physical and chemical attributes of the industrial tomato, hybrid U 2006 (harvest 2006): Classification of the raw material, waiting hours in the outside area (Hours), relative humidity (UR), temperature (TC), fresh matter mass (MF), titratable acidity (AT), firmness (FZ), soluble solid content (°Bríx), hydrogen potential (pH), extravasation of electrolytes (EE). Morrinhos, IFGoiano, 2016.

Shift	Serious defects (%)	General defects (%)	Quality (%)	Hours	UR (%)	TC (°C)
			Property A			
Morning	17.40	39.21	43.35	5.0	61.0	24.70B
Afternoon	19.86	33.51	46.63	4.7	62.3	31.39A
			Property B			
Morning	20.48	17.52	61.99	15.6	61.0	23.27B
Afternoon	22.21	26.59	51.19	14.7	62.3	38.86A
	MF (kg)	**AT (%)**	**FZ (N)**	**°Brix**	**pH**	**EE (%)**
			Property A			
Morning	2.267A	0.53A	1.06A	4.19 A	4.49B	38.39B
Afternoon	2.167A	0.53A	0.85A	4.06 A	4.61A	69.11A
			Property B			
Morning	2.389A	0.52A	1.97A	4.40 A	4.48A	28.10B
Afternoon	2.178B	0.55A	0.86B	4.14B	4.67A	72.35A

Averages followed by same letters in the column do not differ from each other, Tukey test, 5% significance.

Table 3. Physical and chemical attributes of the industrial tomato, hybrid U 2006 in processing steps (harvest 2016): temperature (TC), fresh matter mass (MF), titratable acidity (AT), firmness (FZ), soluble solid content (°Bríx), hydrogen potential (pH), extravasation of electrolytes (EE). Morrinhos.IFGoiano. 2016.

Shift	Step	TC (ºC)	MF (kg)	AT (%)	FZ (N)	ºBrix	pH	EE (%)
Property A								
Morning	Manual	28.67A	2125.75BC	0.58A	0.96A	3.90A	4.72A	52.75A
	Mechanized	27.57A	2607.50A	0.41B	1.57A	4.05A	4.64A	11.50BC
	Truck	27.12A	2468.00AB	0.60A	1.53A	4.22A	4.59A	39.19ABC
	Industry	30.62A	2256.5ABC	0.38B	0.59A	4.05A	4.05A	9.64C
	Unloading	17.02 B	1946.50 C	0.65A	1.15A	4.45A	4.45A	49.35 AB
	Mat	17.22 B	2197.0ABC	0.59A	0.56A	4.50A	4.50A	67.92 A
Afternoon	Manual	37.65A	2274.50A	0.50A	1.36A	3.80CD	4.61A	71.04A
	Mechanized	30.32B	2387.75A	0.57A	0.91A	3.82BCD	4.55A	59.94A
	Truck	31.72B	2170.50A	0.52A	1.22A	3.17 D	4.70A	73.27A
	Industry	39.02A	1704.50B	0.60A	0.69A	4.17 BC	4.57A	68.53A
	Unloading	25.45C	2090.50AB	0.50A	0.60A	4.47 AB	4.68A	55.55A
	Mat	24.20C	2375.50A	0.51A	0.22A	4.92 A	4.58A	86.35A
Property B								
Morning	Manual	22.02BC	2280.50 B	0.54AB	1.57 A	5.00 A	4.64 A	35.03A
	Mechanized	21.95BC	2935.00A	0.28B	1.25A	4.07B	4.82A	20.44A
	Truck	17.32C	2291.75B	0.61AB	2.77A	4.25B	4.65A	24.36A
	Industry	30.62 A	2130.50 B	0.37 B	1.91A	4.35B	4.69A	48.92A
	Unloading	22.27BC	2500.75 B	0.59AB	1.98A	4.25B	4.50A	23.39A
	Mat	22.45AB	2194.50 B	0.64 A	2.34 A	4.47AB	4.58 A	16.57A
Afternoon	Manual	45.62 A	2259.00 AB	0.57A	1.46A	4.05 A	4.71A	73.56A
	Mechanized	38.62 B	2268.00AB	0.57A	1.99A	4.20 A	4.61A	71.87A
	Truck	36.27 B	2151.50B	0.47A	0.31A	3.95 A	4.64A	68.11A
	Industry	40.17AB	2562.00 A	0.54A	0.77A	4.02 A	4.66A	63.04A
	Unloading	37.20 B	1697.25 C	0.53A	0.33A	4.20 A	4.71A	69.17A
	Mat	35.30 B	2127.00 B	0.59A	0.29A	4.35 A	4.72A	88.33A

Averages followed by same letters in the column do not differ from each other by Tukey test, 5% significance.

the afternoon. Titratable acidity at high temperature did not increase the consumption of reserves and the activation of organic acids both in the morning and afternoon shifts (Table 2).

For firmness, in properties A and B no significant differences were verified during the steps.

In property A, in the morning, average °Bríx was 4.19 and 4.06 in the afternoon. Thus, no significant differences were noticed. In property B, average °Bríx was 4.40 in the morning and 4.14 in the afternoon.

In property A in the afternoon and B in the morning, the authors verified an increase in SST. According to Echeverria & Ismail (1990), an increase in SST is noticed after harvest. It may happen due to conversion of organic acids to intermediate glycolytics and subsequent to hexoses or the release of soluble sugars by other glycolytics such as starch hydrolysis, being the results of biological activities.

For pH, property A (Table 2) showed significant differences, whereas no significant differences were noticed in property B (Table 2). Properties A and B (Table 3) did not show any statistically significant oscillations.

Extravasation of electrolytes in properties A and B (Table 2) is higher in the afternoon. High temperatures changed the composition and structure of membranes, resulting in release of electrolytes (Kerbauy, 2012), leading to a loss of fresh matter and water. In property A, in the morning, the authors observed some changes within the steps with higher releases of electrolytes in the beginning of manual step and in the last step on the mat obtaining an atypical result. Properties A, in the afternoon, and B, in the morning and in the afternoon, showed no significant differences, using Tukey test at 5%.

Given the above, an increase in serious defects was observed over 10 hours of standby time, in the outside area. This fact resulted in a discount on the amount paid for the cargo, and also a higher loss in fresh mass. High temperature caused changes in composition and structures of membranes, and also releases of electrolytes, mainly in the afternoon shift.

The most critical points were arrival at industry and unloading, in which losses of water as well as fresh mass were clearly observed, due to high temperature and for being longer time in the sun and pressed in the container during the waiting time.

The authors suggest better logistics related to arrivals and communication when restricting crops due to unscheduled stops in the industry which increase waiting time.

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