Quality of grape tomatoes in differents cultivation systems

Qualidade do tomate do tipo grape em diferentes cultivos

Calidad de los tomates uva en diferentes cosechas

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André Mesquita Rocha
ORCID: https://orcid.org/0000-0001-8842-9618
Universidade Federal de São João del Rei, Brasil
E-mail: andremrochamg@gmail.com
Andreia Aparecida dos Anjos Chagas
ORCID: https://orcid.org/0000-0002-8835-828X
Universidade Federal de São João del Rei, Brasil
E-mail: andreiachagas.ufsj1@gmail.com
Gabriela Conceição Oliveira e Silva
ORCID: https://orcid.org/0000-0001-6004-5348
Universidade Federal de São João del Rei, Brasil
E-mail: gabrielaconceicao181@hotmail.com
Ernani Clarete da Silva
ORCID: https://orcid.org/0000-0001-7515-7588
Universidade Federal de São João del Rei, Brasil
E-mail: clarete@ufsj.edu.br
Washington Azevedo da Silva
ORCID: https://orcid.org/0000-0001-9536-9238
Universidade Federal de São João del Rei, Brasil
E-mail: was@ufsj.edu.br
Lanamar de Almeida Carlos
ORCID: https://orcid.org/0000-0001-8356-2583
Universidade Federal de São João del Rei, Brasil
E-mail: lanamar@ufsj.edu.br

Abstract

Tomato is a fruit rich in bioactive compounds like lycopene, vitamin C and phenolic compounds. However, cultivation conditions can influence the concentration of these substances. In this study, the objective was to analyze quality characteristics of tomato fruits in different cultivation systems. The following characteristics were evaluated: pH, soluble solids content, total acidity, relationship between soluble solids content and total acidity, instrumental color parameters (L *, a *, b *, chroma and hue), texture, bioactive compounds (total carotenoids, lycopene, total phenolic compounds and vitamin C) and antioxidant activity of grape tomato fruits grown in a greenhouse in different systems (soil x substrate). A completely randomized design was used, with two treatments and four replications. The analysis were performed by official methods and in triplicate. The pH, soluble solids, texture, color, lycopene, vitamins C and antioxidant activity were not affected by the cultivation system used. However, grape-type tomatoes grown in substrate showed higher levels of carotenoids (36.31 μg.100 g^{-1} fresh matter), phenolic compounds (68.37 mg GAE.100 g^{-1} fresh matter) and ratio between total soluble solids and total acidity (17.90), and lower total acidity (0.58% citric acid 100 g^{-1}), which represents a nutritional, sensorial and functional advantage for the consumer.

Keywords: *Solanum lycopersicum*; Bioactive compounds; Greenhouse crop.

Resumo

O tomate é uma fruta rica em compostos bioativos como licopeno, vitamina C e compostos fenólicos. Entretanto, as condições de cultivo podem influenciar na concentração dessas substâncias. Neste estudo, o objetivo foi analisar características da qualidade dos frutos de tomateiro em diferentes sistemas de cultivo. As seguintes características foram avaliadas: pH, teor de sólidos solúveis, acidez total, relação entre o teor de sólidos solúveis e a acidez total, parâmetros instrumentais de cor (L*, a*, b*, croma e hue), textura, compostos bioativos (carotenoides totais, licopeno, compostos fenólicos totais e vitamina C) e atividade antioxidantes de frutos de tomateiro do tipo *grape* cultivado em casa de vegetação em diferentes sistemas (solo x substrato). Utilizou-se delineamento inteiramente ao acaso, com dois tratamentos e quatro repetições. As análises foram realizadas por métodos oficias e em triplicata. O pH, sólidos solúveis, textura, cor, licopeno, vitamina C e atividade antioxidante não foram afetadas pelo sistema de cultivo usado. Porém, os tomates tipo *grape* cultivados em substrato apresentaram maiores teores de carotenoides (36,31 μg.100 g^{-1} base fresca), compostos fenólicos (68,37 mg GAE.100 g^{-1} base fresca) e relação entre os sólidos solúveis totais e a acidez total (17,90), e menor acidez total (0,58% ácido cítrico 100 g^{-1}), o que representam do ponto de vista nutricional, sensorial e funcional, benefícios para o consumidor.

Palavras-chave: *Solanum lycopersicum*; Compostos bioativos; Cultivo em estufas.

Resumen

El tomate es una fruta rica en compuestos bioactivos como licopeno, vitamina C y compuestos fenólicos. Sin embargo, las condiciones de cultivo pueden influir en la concentración de estas sustancias. En este estudio, el objetivo fue evaluar características de calidad de frutos de tomate en diferentes sistemas de cultivo. Se evaluaron las siguientes características: pH, contenido de sólidos solubles, acidez total, relación entre contenido de sólidos solubles y acidez total, parámetros instrumentales de color (L *, a *, b *, croma y hue), textura, compuestos bioactivos (carotenoides totales, licopeno, compuestos fenólicos totales y vitamina C) y actividad antioxidante de frutos de tomate del tipo *grape* cultivados en invernadero en diferentes sistemas (suelo x sustrato). Se utilizó un diseño completamente al azar, con dos tratamientos y cuatro repeticiones. Los análisis se realizaron por métodos oficiales y por triplicado. El pH, los sólidos solubles, la textura, el color, el licopeno, la vitamina C y la actividad antioxidante no se vieron afectados por el sistema de cultivo utilizado. Sin embargo, los tomates tipo *grape* cultivados en substrato mostraron niveles más altos de carotenoides (36,31 µg.100 g^{-1} de base fresca), compuestos fenólicos (68,37 mg de GAE.100 g^{-1} de base fresca) y relación entre sólidos solubles totales y acidez total (17,90), y menor acidez total (0,58% ácido cítrico 100 g^{-1}), lo que representa una ventaja nutricional, sensorial y funcional para el consumidor.

Palabras clave: *Solanum lycopersicum*; Compuestos bioactivos; Cultivo en envernadeiro.

1. Introduction

The cherry and grape tomatoes (*Solanum lycopersicum*) are among the most popular varieties in the world. In recent years its cultivation and commercialization have been boosted throughout Brazil, as it is a delicate fruit, of reduced size, sweet taste and attractive red color, because of the high content of lycopene (Guilherme et al., 2014). Due to these characteristics, the *grape* tomatoes are now well incorporated into modern gastronomy as garnishes, appetizers and in the preparation of various dishes (Silva et al., 2011).

Recent studies recommend its consumption, as it is a well-known fruit in terms of its content of bioactive compounds that contribute both to its nutritional value and to the maintenance of the consumer’s health, since they have antioxidant compounds, such as carotenoids (lycopene, lutein and β-carotene), vitamins (vitamin E and C) and phenolic compounds (caffeic acid and quercetin) (Luterotti et al., 2015). These compounds act directly on the body as antioxidant agents, helping to prevent diseases such as cardiovascular disease, cancer, Parkinson's and Alzeheimer. In addition, they assist the body in removing free radicals formed, mainly due to poor diet and stress conditions (Hallmann, 2012).

Therefore, in addition to vitamins, carotenoids and phenolic compounds, other properties such as color, firmness, sugar concentration and organic acids, which are responsible for the flavor, are also directly related to the quality of the fruits (Tinyane et al., 2013). According to Levya et al. (2013), these properties can be changed according to genetic differences, cultivation techniques, post-harvest storage conditions and environmental conditions such as humidity, light and temperature.

Due to the growing demand for high quality vegetables comes the need for the adoption of sustainable cultivation techniques aiming to save natural resources, reducing water consumption, reducing or eliminating pesticides, as well as reducing the distance between the production unit and distribution to shopping centers in urban areas.

The greenhouse crops cultivated in the soil, hydroponic or with fertigation in substrate, with partial control of the environment allows for an increase in productivity and obtaining better quality products, being thus considered the most suitable and the most used for the production of the majority of cultivated vegetable species. In this context, the present study aimed to analyze the quality characteristics of tomato fruits in different types of cultivation.

2. Methodology

Materials and Methods

The experiment was carried out in a greenhouse with a capacity of 1600 plants, built in a metallic structure, in the type of arched ceiling with 4 m high, covered with polyethylene film additive of UV stabilizers, 200 microns thick, located on the Pampulha farm, in the municipality of Pará de Minas-MG, under the geographic coordinates (Lat. 019º18'16”S Long. 044º61'98”W).

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The experimental design adopted was entirely randomized (Ferreira, 2018) with four replications including two treatments: cultivation in the soil and cultivation in pots with a capacity of 10 liters filled with substrate based on coconut fiber. The plots in the soil consisted of single rows of 10 plants spaced 60 centimeters apart and the fruits of the six central plants were evaluated, as were the plants conducted in the pots.

The tomato seedlings of the hybrid cultivar Tomini were produced in 96-cell plastic trays, using commercial substrate. At 30 days after sowing, the seedlings were transplanted to the defined location according to the experimental design. The environmental control was carried out in order to allow a temperature of 27ºC ± 3, relative humidity around 70% ± 3 and a wind speed of 2.4 km h^{-1} (exhaust fan on).

The soil used in the experiment was a dystrophic oxisol that initially had the following characteristics: P = 1.15 mg dm^{-3}; K = 72.0 mg dm^{-3}; Ca = 2.31 cmoc dm^{-3}; Mg = 1.43 cmoc dm^{-3}; Al = 0.02 cmoc dm^{-3}; sum of exchangeable bases = 3.92 cmoc dm^{-3}; cation exchange capacity = 6.52 cmoc dm^{-3}; base saturation = 60.1%; organic matter = 46.2 g dm^{-3}.

In both treatments, the plants were automatically fertigated using the equipment (Hidrosense - RF4) with volumetric injectors adjusted to 1.2% so that the electrical conductivity of the applied solution remained at 2.5 mS/cm. The nutrients in quantity were diluted in water according to what is established by the Soil Fertility Commission of Minas Gerais, Fifth Approximation based on the analytical result of the soil.

The plants were carried out with two stems and tutored vertically with the aid of ribbons. All cultural and phytosanitary treatments were carried out according to the needs and recommendations for the culture (Alvarenga, 2013).

Approximately 180 grams of fruit from each plot were harvested. The tomatoes were packed in plastic boxes and transported to the Food Conservation laboratory of the Federal University of São João del-Rei at the Sete Lagoas Campus - MG, where the selection was made, washing in running water, drainage to remove excess of water and, later, physical-chemical analyzes, color, instrumental texture, bioactive compounds (total phenolics, total carotenoids, lycopene, vitamin C) and antioxidant activity.

Physico-chemical characteristics

The hydrogen potential (pH) was determined with the aid of a digital pH meter (Tekna® T-1000), by immersing the electrode in the homogenized sample and adding 50 mL of distilled water (Aoac, 2016).

Total titratable acidity was determined by titrometry, using a 0.01 N NaOH solution as standard and phenolphthalein as an indicator, according to the methodology proposed by Aoac (2016), with assistance of pH measurement. The results were expressed in % citric acid.

he content of total soluble solids (TSS) was evaluated through direct refractometric reading in degrees Brix (ºBrix), using a digital refractometer (REICHERT r2MINI), according to the Aoac methodology (2016).

The ratio of the total soluble solids content to the total titratable acidity (SST / AAT), was also calculated. The colorimetric parameters were evaluated with the aid of a Konica Minolta colorimeter, CR410 in the L* color space, a*, b*, C and Hº, where L* indicates luminosity ranging from 0 (black) to 100 (white), a* refers to how green or red the fruit is, b* indicates coloration in the yellow range in blue, the chromaticity (C) represents the saturation and purity of the color (close to 0 neutral colors and close to 60 vivid colors, the Hue angle (Hº) represents the real color at an angle of 360º. Measurements were made at three points distinct from the equatorial region of each fruit.The results consist of the averages of these readings.

Tomato firmness was determined in a TAXT*PLUS* Texture analyzer (Stable Micro Systems, Godalming, Surrey, UK) equipped with a 50N load cell and Exponent Lite software (Version 5.1.1.0, 2010). For this, the fruits as a whole were fixed in the base of the equipment containing a central hole. Afterwards, a probe with a spherical tip, 2mm in diameter, was moved perpendicularly against the tomato surface until complete rupture, making a distance of 5 mm, at a test speed of 5 mm s^{-1}. From the Force (g) x time (s) curve, the data were automatically compiled by the software, and the firmness of the tomatoes was expressed in Newton.

Bioactive compounds

Total carotenoids content and Lycopene

The lycopene content was determined according to the methodology proposed by Rodriguez-Amaya (2001), which consists in the extraction of carotenoid pigments with acetone p.a and quantification by spectrophotometry at 450 nm for total carotenoids and 470 nm for lycopene. The results were expressed in µg of carotenoids per gram of sample on a fresh basis.

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Total phenolic compounds

The content of total phenolic compounds was determined by the Folin-Ciocalteau method Neves et al. (2009) by comparing a calibration curve constructed with gallic acid. The absorbance was read on a FEMTO 700 S spectrophotometer at 740 nm. The results were expressed in mg of gallic acid equivalent (GAE) per 100 grams of sample on a fresh basis.

Ascorbic acid (Vitamin C)

Vitamin C content was evaluated using high performance liquid chromatography (HPLC) on a HPLC SHIMADZU system prominence LC - 20A, with an LC - 20AT quaternary pump, manual injector with 20 μL loop, degasser, an CBM- 20A integrator and an SPD-20AV DAD detector, ODS-2 HYPERSIL column (250 mm 4.6 mm, 5μm) and CTO-20A oven at 40ºC. The mobile phase was prepared with cetyl-trimethylammonium bromide (5 mmol.L^{-1}) and monobasic potassium phosphate (50 mmol.L^{-1}) in a 1:1 ratio, following the methodology proposed by Benloch et al. (1993) and adapted by Teixeira, (2018).

Antioxidant Activity (AA)

The measure of DPPH radical capturing activity (2,2-diphenyl-1-picrilhidrazil) was determined using the methodology described by Brand-Williams et al. (1995) and adapted by Embrapa, (2016). The absorbance was read on a FEMTO 700 S spectrophotometer at 515 nm wave length. The results were expressed in μmol Trolox equivalent per gram of sample on fresh basis (μmol TE. g^{-1}).

Statistical Analysis

All analysis were performed in triplicate, the data obtained were subjected to analysis of variance by the F test and the means were compared by the Tukey test with a 5% probability using the SISVAR 5.6 software (Ferreira, 2014).

3. Results and Discussion

The Table 1 contain data regarding physical and chemical characterization on tomatoes grown in soil and in substrate. It shows there were significant differences between treatments for the attributes of titratable acidity (TTA), relationship between soluble solids content and total acidity (Ratio), total carotenoids and total phenolic compounds (Table 1).

Table 1. Physico-chemical characteristics and content of bioactive compounds in grape tomatoes grown in pots and directly in the soil.

Attributes	Type of culture system used	
	Substrate	Soil
pH	4,53^{a}	4,60^{a}
TSS (^{o}Brix)	8,64^{a}	8,73^{a}
TTA (% citric acid)	0,58^{a}	0,81^{b}
Ratio	14,90^{a}	10,78^{b}
Texture (N)	5,23^{a}	5,03^{a}
L*	38,44^{a}	39,47^{a}
a*	11,19^{a}	10,69^{a}
b*	15,04^{a}	13,87^{a}
Croma (C*)	18,75^{a}	17,51^{a}
Hue (h^{o})	53,36^{a}	52,40^{a}
Licopene (µg. g^{-1} fresh basis)	30,10^{a}	32,44^{a}
Total Carotenoids (µg. g^{-1} fresh basis)	36,31^{a}	32,54^{b}
Fenolics Compounds (mg GAE.100 g^{-1} fresh basis)	65,37^{a}	53,00^{b}
Vitamin C (µg.100g^{-1} fresh basis)	1314,39^{a}	1572,11^{a}
Antioxidant Activity (µmol TE.g^{-1} fresh basis)	128,88^{a}	126,70^{a}

** Averages followed by the same letter horizontally do not differ by Tukey's test with 5% probability (GAE: Gallic acid equivalent; TTA: total titratable acidity, Ratio: relationship between soluble solids content and total acidity).
Source: Elaborated by the authors.

There were no significant difference between treatments in relation to pH, and the pH values observed in these studies are higher than the results obtained by Vieira et al. (2014), who found in studied similar tomatoes, obtained via organic and conventional cultivation, pH values in the range of 4.46 and 4.48. According to Ramos et al. (2013), the pH can vary with the cultivation conditions, however it is desirable that these values are low to reduce the incidence of microorganisms.

The total soluble solids (TSS) content was not affected by the tomato cultivation systems. Sugars, mainly sucrose, are the main soluble solids present in tomatoes. According to Otoni et al. (2012), light, temperature and relative humidity, are factors that can affect photosynthesis and consequently influence the concentration of sugars in the fruits.

The total titratable acidity had a significant variation, the highest values being found in tomatoes grown in soil (0.81% citric acid). Monteiro et al. (2019), evaluating the postharvest quality of cherry tomatoes grown in an agroecological system, found values of total titratable acidity of 0.31%, values lower than those found in this study. According to Oliveira et al. (2016), such a reaction may have been influenced by the metabolism response to the culture system.

Borguini et al. (2013) have reported that pH and total acidity are important elements when studying the level of acceptance of a product by the consumer, as fruits that are too acidic are in general more rejected by consumers.

With regard to the TSS/TTA, pot-grown tomatoes presented a significantly higher value (14.90) than tomatoes grown in soil (10.78), although both were considered to be good quality and pleasant taste, as they reached values greater than 10 (Kader et al., 1978). According to Vieira et al. (2014), when these values are high,the fruit is in a good degree of ripeness, due to an increase of SST values as the total acidity values decrease. Sousa et al. (2011) working with tomatoes in a greenhouse obtained very high values, ranging from 30.34 to 48.8, values considered higher when compared to others seen in the literature, that report values ranging from 12.60 to 15.40 (Cardoso et al., 2006).

It was observed that, for pulp firmness, there was no significant difference between treatments, with an average of 5.23 N for pot-grown tomatoes and 5.03 N for tomatoes grown in soil. Islam et al. (2018), evaluating the physical characteristics of cherry tomatoes after harvest, found averages of 18.90 N, higher than the values found in this study. The firmness of the pulp is another important quality characteristic for the commercialization of tomatoes, considering that this parameter is quite required by consumers, which significantly influences the purchase option (Ferreira et al., 2012). It is worth mentioning that firmness is also very important in the fruit's useful life, as it provides greater resistance to damage during harvesting, transportation and marketing.

There was no significant variation in instrumental color parameters, and the values observed for L*, b* and ho were similar to those obtained by Monteiro et al. (2019) for ripe cherry tomatoes, namely L* = 37.14 ± 1.42; b* = 14.54 ± 1.36 and h° = 44.25 ± 8.42. However, the parameters a* and C* obtained in this study were lower than those reported by Monteiro et al. (2018) (a* = 19.87 ± 0.37; C* = 24.29 ± 0.68) for ripe cherry tomatoes. The cherry tomato fruits analyzed by Sousa et al. (2015), exhibited coloration tending slightly to yellow and strongly to red and with high luminosity. The results achieved in the present study differ from those obtained when the cherry tomatoes grown in the protected system in different cultivation were evaluated.

The averages of the chromatic coordinate a* referring to the color that varies in the red axis (+a) to the green (-a), indicate the intensity of the red color, an important sensory attribute that makes the product more attractive to the consumer, influencing positively in buyer’s choice.

When the lycopene concentration in the fruits was evaluated, it was observed that the cultivation systems did not influence this characteristic (Table 1). However, the values observed in these studies are lower than the results obtained by Shirahige et al. (2010), (4,544.96 µg.100 g^{-1} in fresh basis) for Santa Cruz tomatoes. The concentration of lycopene in tomatoes depends on its chemical constitution, genetics and interaction of the genotype with the environment in which it is inserted (Ceballos et al., 2012).

In contrast, the total carotenoid contents were statistically different in response to treatments (Table 1). Pot-grown tomatoes showed a higher average of carotenoids (36.31 µg.100 g^{-1} in fresh basis) than tomatoes grown in soil (32.54 µg.100 g^{-1} in fresh basis). However, the values detected in this experiment were lower than those reported by Pinho, (2008), which, evaluating the physical-chemical quality of cherry tomatoes of the cultivar “Carolina” in conventional and organic crops, found values of (41.29 µg.100 g^{-1} and 47.98 µg.100 g^{-1} on a fresh basis), respectively.

The contents of phenolic compounds were higher in pot-grown tomatoes (65.37 mg GAE.100 g^{-1} in fresh basis) when compared to those grown in soil (53.00 mg GAE.100 g^{-1} in fresh basis). The contents of bioactive compounds can vary with abiotic factors such as light, temperature, humidity, and ionizing radiation (Rivera-Pastrana et al., 2010), which in this study were minimized by the fact that the tomatoes were grown in the same protected environment.

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Regarding to antioxidant activity, they did not differ statistically between treatments. According to Vasconcelos et al. (2014), antioxidants in fruits are substances that can prevent or repair oxidative damage caused by reactive oxygen species in lipids, proteins and nucleic acids.

The average vitamin C content did not show any significant difference, ranging from (1,314 $mg.100g^{-1}$ to 1,572 $mg.100g^{-1}$ on a fresh basis) between treatments (Table 1). Guimarães et al. (2020), evaluating a “Compack” type tomato, found average vitamin C values of 29.303mg. $100g^{-1}$ in fresh basis, therefore, higher than those found in the present study.

According to Gautier et al. (2005), fruits that are less exposed to light, as in a protected environment, have a higher concentration of vitamin C, a fact that was observed in this study when compared to others found in the literature that report values that vary from (4.60 and 4.58 mg 100 g^{-1} in fresh basis), in “Carolina” tomatoes grown in the field (Almeida, 2016).

4. Final Considerations

It was considered that only carotenoids, phenolic compounds, total soluble solids/total acidity and total acidity are affected by the cultivation system whose contents obtained with the cultivation in substrate represent, from the nutritional, sensory and functional point of view, benefits for the consumer.

Future research relating different levels of nutrients available in the soil solution and the desired characteristics of the fruit in order to maximize the efficiency of nutrient use and decrease nutrient losses. Studies regarding the productivity and sensorial characteristics would enlighten further aspects.

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Percentage of contribution of each author in the manuscript

André Mesquita Rocha - 20%

Andreia Aparecida dos Anjos Chagas - 20%

Gabriela Conceição Oliveira e Silva - 10%

Ernani Clarete da Silva - 20%

Lanamar de Almeida Carlos - 20%

Washington Azevedo da Silva - 10%