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Biometric, Physical-Chemical And Microbiological Quality Indicators Of Tomatoes (Solanum Lycopersicum) Sold In Fairs And Supermarkets After Different Sanitization Treatments

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Abstract:
As a perishable food, tomatoes have high humidity and nutritional conditions that favor the development of microorganisms and can put the health of those who eat them at risk. Thus, when tomatoes are consumed fresh, without being sanitized, they propagate pathogenic microorganisms, putting the consumer's health at risk. The aim of this study was to evaluate the physicochemical parameters and the incidence of microorganisms in salad tomatoes sold in street markets and supermarkets in the city of Paraíso do Tocantins after different sanitization treatments. A total of 100 tomato samples were purchased from supermarkets (MB, XP and TQ) in the West Zone (ZO) and the free market (CF) in the city of Paraíso do Tocantins. The fruit was transported to the Food Analysis and Fruit and Vegetable Processing Laboratories at the Federal Institute of Tocantins IFTO Paraíso do Tocantins campus, for biometric assessment (fruit mass, transverse and longitudinal diameters), treatment without sanitization, treatment with running water and treatment with 100 ppm sodium hypochlorite solution for 20 minutes, physicochemical evaluations (pH, total titratable acidity, total soluble solids, vitamin C and humidity) and microbiological quality (total coliforms, thermotolerant coliforms, Escherichia coli and evaluation of the presence of Salmonella sp.). The biometric analysis showed a mass of 178.20 grams, a transverse diameter of 72.46 millimeters and a longitudinal diameter of 57.82 millimeters. The physical-chemical evaluation showed average values for pH of 4.34, titratable acidity of 0.24%, soluble solids of 5.81 brix, humidity of 94.94% and vitamin C of 11.27 mg. There were total coliform counts of 1058 NMP/g, thermotolerant coliforms of 150.5 NMP/g, Escherichia coli of 13.15 NMP/g and no Salmonella sp. Treatment with 100 ppm sodium hypochlorite solution for 20 minutes reduced the amount of total coliforms by 97.91%, thermotolerant coliforms by 93.01% and Escherichia coli by 71%. The tomatoes sold in the city of Paraíso presented fruit within the physical-chemical and microbiological quality standards established by the legislation, so the tomatoes can be consumed without risk to the health of the consumer regardless of the establishment of purchase.

Keywords: *Northern region; fruit, public health; microorganism; physicochemical analysis.*

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I. Introduction

The salad tomato, Solanum Lycopersicon, is a fruit from the Solanaceae family with a flat globular shape. It has a thick flesh, high acidity and a high percentage of water [1]. Abundant in calcium, phosphorus, iron and potassium, it has a high content of lycopene (carotenoid), vitamins C and E, as well as a variety of antioxidant compounds, phenolics and flavonoids [2], [3]. It has nutritional benefits for the health of those who consume it [4], [5], [6]. The fruit can be used in the daily diet of the Brazilian population in different ways, such as fresh, sauces, extracts, salads and pulp [7]. As a perishable food, tomatoes have high humidity and nutritional conditions, favoring the development of microorganisms, which can put the health of those who eat them at risk [8].

Marketing environments without infrastructure, basic sanitation, lack of organization and traders or handlers who are unaware of good handling and marketing practices have a high potential for biological contamination [9], [10]. Thus, when tomatoes are consumed fresh, without being cleaned and sanitized, they act to spread pathogenic microorganisms, putting the consumer's health at risk, because depending on the type of virus or parasite acquired, it can lead to death [11].

The evaluation of physicochemical indicators is of paramount importance for monitoring the quality of food products [12]. Quality assurance is made up of a sequence of methods and operational activities that seek to verify the quality of the fruit after production [13]. The specific parameters used to ensure quality guarantee the safety of the product's consumption, the determinations established by legislation in Brazil, as well as the health and requirements of the consumer [14]. In this sense, according to [15], all food produced must respect consumer food safety.

There are few reports in the literature on the physicochemical and microbiological characteristics of tomatoes sold in cities in Brazil's northern region [7]. Therefore, considering the high consumption of tomatoes in the city of Paraíso do Tocantins, state of Tocantins, the hygienic and sanitary quality of this fruit is of the utmost importance, in order to avoid the spread of microorganisms and consequently food-borne diseases [16]. Within this context, [17] explains the importance of carrying out laboratory tests to assess the levels of microbial contamination in food, since it is impossible for consumers to be able to carry out this analysis at the time of purchase.

The aim of this study was to evaluate the physicochemical parameters and the incidence of microorganisms in salad tomatoes sold in open-air markets and supermarkets in the city of Paraíso do Tocantins, after different sanitization treatments.

II. Material And Methods

This is a quantitative experimental study carried out at the Federal Institute of Education, Science and Technology of Tocantins - IFTO: Paraíso do Tocantins campus. Five monthly tomato samples were randomly collected from five (5) commercial establishments, three (3) supermarkets (BM, PX and TQ) and one (1) free market (CF) located in the city of Paraíso do Tocantins, from March to June 2024, totaling 100 tomato samples. The samples were packed in sterile airtight containers and transported in a thermal box for analysis at the Microbiology and Food Analysis Laboratories of the Paraíso do Tocantins Campus - IFTO.

Biometric characterization of tomatoes.

The fruits were individually evaluated, following the adapted methodological procedures used by [18], in relation to fruit mass (g), transverse diameter (mm) and longitudinal diameter (mm).

Physico-chemical analysis

The physicochemical characteristics followed the procedures of the physicochemical methods for food analysis of the Adolfo Lutz Institute. The analyses of titratable acidity ATT (% citric acid), pH, total soluble solids SST (brix), humidity and vitamin C (% ascorbic acid) were carried out in triplicate [19].

Microbiological analysis

The tomato samples were exposed to three (3) sanitization treatments: tomatoes without sanitization (TSH), sanitization with drinking water (THA) and 100 ppm sodium hypochlorite solution for 20 min (THH). The determination of total coliforms 35 °C, thermotolerant coliforms 45 °C, Escherichia coli and Salmonella were carried out according to the methodology described by [20] and the results were compared with Normative Instruction - IN no. 161, of July 1, 2022 of the National Health Surveillance Agency - ANVISA [21], which provides for microbiological standards for food.

Statistical analysis

In order to check whether there was a significant difference between the results, ANOVA analysis of variance will be applied and Tukey's test will be applied between the means of the response variables at a 5% significance level. All the statistical analyses were carried out using the SISVAR program version 5.6 [22]. Principal Component Analysis (PCA) will assess the interrelationship between the data and the treatments, with the aim of grouping the physico-chemical and microbiological variables according to their similarity. It will address the generation, selection and interpretation of the components investigated and determine the variables with the greatest influence on the formation of each component. The PCA analysis was carried out using the PAST software [23].

III. Result And Discussion

The results of the biometric analysis of the fruit are shown in Table 1. There was a significant difference ($p<0.05$) between the treatments for the biometric variables evaluated.

Table 1. Biometric analysis of tomatoes in different marketing locations.

Treatment	Mass (g)	Transverse diameter (mm)	Longitudinal diameter (mm)
MB	$170.468^{C} \pm 3.101$	$71.687^{B} \pm 0,186$	$56.817^{B} \pm 0,987$
PX	$176.993^{B} \pm 1,881$	$71.072^{B} \pm 0,639$	$55.911^{B} \pm 0,568$

TQ	169.919^{C}± 2.712	71.956^{B}± 0,094	55.749^{B} ± 0,534
CF	195.437^{A} ± 3.989	75.116^{A} ± 0,513	62.816^{A} ± 0,717
Coefficient of variation (CV%)	1.650	0.600	1.210

Different letters in the columns differ statistically (p<0.05)
Source: Authors (2024)

The CF treatment showed a significant difference, with higher values for mass, transverse diameter and longitudinal diameter than the MB, PX and TQ treatments. The MB treatment had the lowest values for mass, transverse diameter and longitudinal diameter. In a study on the post-harvest quality of tomatoes in different establishments in the city of São Luís, Maranhão, [24] found lower results than those found in this study. Research carried out by [25] also found an average result for tomato mass (144 g) lower than that found in this study (178.20 g). According to [24], the mass of the tomato is related to the cultivar and is not recommended by legislation, but consumers give importance to the size and mass of the tomato at the time of purchase. Consumers of salad tomatoes prefer fruit with a larger diameter when buying [26].

The shape of tomatoes can be characterized by their longitudinal and transverse diameters, because when the longitudinal diameter is less than or equal to the transverse diameter, the fruit is classified as round [26]. Normative Instruction 33/2018 of the Ministry of Agriculture, Livestock and Supply MAPA [27] classifies tomatoes according to their transverse diameter and different classes or sizes, such as giant, large, medium and small. Thus, all the treatments had tomatoes classified as round, with a longitudinal diameter smaller than the transverse diameter and special size (transverse diameter greater than 65 to 75 mm) [27].

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The results of the physical and chemical parameters analyzed are shown in Table 2. There was a significant effect (P<0.05) for the treatments and variables evaluated.

Table 2. Physical-chemical analysis of tomatoes from different marketing locations.

Treatment	ATT (%)	pH	SST (brix)	Moisture (%)	Vitamin C (mg%)
MB	0.23^{B} ± 0,12	4.00^{C} ± 0,43	5.73^{A}± 0,26	94.79^{A}± 0,44	10.83^{A}± 1,65
PX	0.27^{A} ± 0,01	4.04^{BC} ± 0,01	5.83^{A}± 0,05	94.95^{A}± 0,27	11.05^{A}± 2,12
TQ	0.27^{A} ± 0,17	4.49^{AB} ± 0,05	5.85^{A}± 0,06	94.97^{A}± 0,85	11.39^{A}± 1,68
CF	0.21^{B} ± 0,11	4.86^{A} ± 0,02	5.85^{A}± 0,06	95.05^{A}± 0,62	11.81^{A}± 1,13
Média	0.24	4.34	5.81	94,94	11.27
CV%	9.20	5.00	3.79	0.48	15.15

ATT - Titratable acidity, STT - Total soluble solids, CV - Coefficient of variation
Different letters in the columns differ statistically (p<0.05)
Source: Authors (2024)

The physical chemical parameters total titratable acidity (ATT%) and pH showed significant differences. These differences can be explained by the method of cultivation, harvest period, post-harvest processing [12] and the ripening stage of the fruit, as the reduction in acidity is related to the ripening of the tomato [29].

The CF treatment showed higher values for pH, TSS (brix), moisture (%) and Vitamin C (mg%), which did not differ statistically from the soluble solids TSS (brix), moisture (%) and Vitamin C (mg%) of the MB, PX and TQ treatments. The MB treatment showed the highest value for titratable acidity ATT%.

As there is no specific legislation for the physicochemical evaluation of tomatoes, Normative Instruction SDA No. 37 of 01/10/2018 of the Ministry of Agriculture, Livestock and Supply MAPA was adopted, which establishes the identity and quality standards for tomato juice [30].

Table 3. Identity and quality standards for tomato juice.

Parameter	Minimum	Maximum
Soluble solids in °Brix at 20° C	5	-----------------
pH	-----------------	4.5
Total acidity expressed as citric acid (g/100g)	-----------------	0.5

Fonte: https://www.legisweb.com.br/legislacao/?id=368178

The CF treatment had a pH above that allowed by law. Acidity and pH are parameters that interfere with the sensory and microbiological characteristics of tomatoes, influencing their acceptance by consumers [31]. Research carried out by [32], on the quality of table tomato fruit, shows results on a better shelf life, as well as a more acidic taste in more acidic tomatoes. Metabolic processes are intensified during senescence, transforming sugars into acids, allowing the pH to rise [33]. Evaluating the post-harvest quality of tomatoes sold at street markets, [34] found values for titratable acidity ATT equal to 0.2400, which is lower than the value found in this study. However, [31] analyzing the use of coatings on tomatoes over time found similar ATT values of 0.2631 and 0.2670 to those found in this study.

The MB, XP, TQ and CF treatments had soluble solids TSS values within the legal limits. Soluble solids are a very important parameter in the food sector, as they assess the degree of ripeness of fruit and indicate the quantity of substances, mainly sugars, present in these foods [35].

This legislation does not include minimum or maximum values for moisture and vitamin C content. Results reported by [29] evaluating the centesimal composition of cherry tomatoes obtained in Goiás were similar to those found in this study. [36] and [37] reported moisture values of 92.03% and 91.48% respectively, which were lower than those found in this study. Moisture corresponds to the total water content of a foodstuff, which influences the chemical and microbiological stability of food products. This intrinsic parameter is generally expressed as a percentage by weight on a wet basis [7].

Studies carried out by [38], evaluating the vitamin C content in tomatoes irradiated with ultraviolet radiation, found average values, respectively, for samples A and B equal to 16.91 $mg.100g^{-1}$ and 10.55 $mg.100g^{-1}$, without statistical significance. Studies on the chemical and physical characterization of fruit from different tomato accessions in a greenhouse, carried out by [39], found average variations in vitamin C content equal to 33.832 $mg.100g^{-1}$ to 42.656 mg. $100g^{-1}$ of pulp, which are higher than those found in the present study. Tomatoes picked ripe have a higher vitamin C content than tomatoes that complete their ripening process outside the tomato plant [40].

Table 4 shows the results of the microbiological analysis of tomatoes sold in street markets and supermarkets in the city of Paraíso do Tocantins. There was no significant effect ($p>0.05$) for the treatments and variables evaluated.

Table 4. Microbiological analysis of tomatoes sold in different locations.

Treatment	CT (NMP/g)	CTT (NMP/g)	EC (NMP/g)	*Salmonella* (UFC/g)
MB	$1.03 \times 10^{3\,A} \pm 57.73$	$1.2 \times 10^{2A} \pm 10.00$	$1.23 \times 10^{1A} \pm 2.31$	Absence
XP	$1.00 \times 10^{3A} \pm 100.00$	$1.51 \times 10^{2A} \pm 88.01$	$1.20 \times 10^{1A} \pm 1.73$	Absence
TQ	$1.06 \times 10^{3A} \pm 57.73$	$1.21 \times 10^{2A} \pm 28.51$	$1.33 \times 10^{1A} \pm 2.08$	Absence
CF	$1.13 \times 10^{3A} \pm 57.73$	$2.1 \times 10^{2A} \pm 60.00$	$1.5 \times 10^{1A} \pm 1.00$	Absence
Média	1058	150,5	13,15	------------------------
CV%	6.49	27.98	9.39	------------------------

CT – Total coliforms, CTT – Thermotolerant coliforms, EC – Escherichia coli, CV – Coefficient of variation
Different letters in the columns differ statistically from each other ($p<0.05$)
Source: Authors (2024)

Under the conditions evaluated, it was found that the CF treatment presented the highest mean values for CT, CTT and EC, the MB treatment presented the lowest values for CT and CTT and the EC treatment presented the lowest value for EC. Normative Instruction nº. 60, of December 23, 2019 [21], establishes microbiological standards for foods. The microbiological parameters for "In natura" fruits and derivatives are shown in table 5.

Table 5. Microbiological standards for fresh fruit foods and derivatives.

	Microorganism	n	c	m	M
"In natura" fruits and derivatives, whole, selected or not	*Salmonella*/25g	5	0	Absence	-
	Escherichia coli/g	5	2	10^2	10^3

Source: https://www.in.gov.br/en/web/dou/-/instrucao-normativa-n-60-de-23-de-dezembro-de-2019-235332356

For fresh fruit, IN no. 60/2019, the standard for Salmonella establishes that 5 sample units must be collected from the tomato (n=5), the aliquot to be analyzed from each sample unit is 25g, and no sample unit (c=0) can present a positive result for Salmonella (m=Absence). The standard for Escherichia coli establishes the collection of 5 sample units from the fruit (n=5), where two sample units (c=2) can present an intermediate result, i.e. between 10^2 (m) and 10^3 UFC (M); and no sample unit can present a result greater than 10^3 (M). The legislation does not establish parameters for total and thermotolerant coliforms.

There was no Salmonella contamination, demonstrating that the samples comply with current legislation, which establishes the absence of Salmonella/25g in fruit and derivatives sold in natura. IN nº. 60/2019 establishes maximum values of 10^2 for Escherichia coli, so values lower than those recommended in the legislation were observed. An evaluation carried out by [41] on the quality of tomatoes produced in Joinville-SC found negative results for total and thermotolerant coliforms. The absence of Salmonella was reported by [42] in samples of cherry tomatoes sold in Viçosa-MG and Escherichia coli and Salmonella by [7] evaluating cherry tomatoes sold in emporiums in Manaus-AM.

The tomato samples were exposed to treatments without sanitization (TSH), sanitized with drinking water (THA) and with sodium hypochlorite solution (THH). Table 6 expresses the average microbiological results of the establishments after the treatments.

Table 6. Microbiological standards after sanitizing treatments.

Local	Treatment	CT (NMP/g)	Reduction (%)	CTT (NMP/g)	Reduction (%)	EC (NMP/g)	Reduction (%)
MB	TSH	1033.00	0%	120.00	0.00%	12.30	0.00%
	THA	246.40	76.14%	20.68	82.76%	7.43	39,58%
	THH	14.38	98.61%	4.65	96.10%	3,43	72,11%
XP	TSH	1000.00	0%	151.00	0.00%	12.00	0.00%
	THA	270.33	72,97%	23.13	84.6%	8.61	28,18%
	THH	15.15	98.48%	11.48	92.39%	3,62	69,79%
TQ	TSH	1000.00	0%	121.00	0.00%	13,30	0.00%
	THA	336.56	66.34%	24.63	79.63%	7,60	42,85%
	THH	16.09	98.39%	11.46	90.53%	3,32	75,04%
CF	TSH	1133.00	0%	210.00	0.00%	15.00	0.00%
	THA	817.46	27.85%	35.04	83.31%	11,45	23,61
	THH	20.95	98.15%	14.65	93.02%	4,94	67,06%

TSH – treatment without hygiene, THA – hygiene treatment with running water, THH – hygiene treatment with 100 ppm sodium hypochlorite solution.

Source: Authors (2024)

The use of the sodium hypochlorite solution led to a 98.61% reduction in TC, 96.10% in TTC and 72.11% in CE in the tomatoes sold at the MB establishment. At the XP establishment, the reduction was 98.48% for CT, 92.39% for CTT and 69.79% for EC. TQ showed a 98.39% reduction in CT, 90.53% in CTT and 75.04% in EC. CF showed a reduction in microbial load of 98.15% for CT, 93.02% for CTT and 67.06% for EC. Hypochlorite is a sanitizing agent that has the power to prevent a large part of the cellular enzyme system of microorganisms from working [43]. The importance of sanitizing fruit and vegetables is to reduce the number of microorganisms with the basic principles of food safety to a level that does not compromise hygienic and sanitary quality [44]. In the results observed by [45], soaking vegetables for 15 minutes in a 200 ppm chlorine solution significantly reduced the load of thermotolerant coliforms and Escherichia coli.

To better interpret the data, the principal component analysis (PCA) was applied to observe similarities or differences between the TSH, THA and THH treatments based on their microbiological characteristics, as shown in Table 6. The PCA therefore organized the data into the two most significant principal components with their respective eigenvalues, explained variance and accumulated variance (Table 4).

Table 04. Principal components (PC), eigenvalues (eigenvalue) and percentage of variance explained.

PC	Eigenvalue %	% variance explained
1	2.84803	94.934
2	0.123369	4.1123

Source: Authors (2024)

The main component PC1 was responsible for 94.934% and the main component PC2 for 4.1123% of the data variations. The sum of principal components 1 and 2 indicated the variability between samples [46]. The weights of the main components CP1 and CP2 for sanitizing treatments are shown in table 5.

Table 5. Highest values in bold of the components for the variations observed.

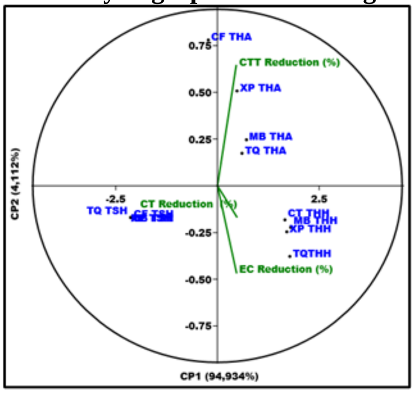
Sanitizing treatments	PC 1	PC 2
MB TSH	-2.1284	**-0.16959**
MB THA	**0.7133**	0.24618
MB THH	**1.799**	-0.22243
XP TSH	-2.1284	**-0.16959**
XP THA	0.48076	**0.5073**
XP THH	**1.7051**	-0.24621
TQ TSH	-2.1284	**-0.16959**
TQ THA	**0.60318**	0.17379
TQTHH	**1.7783**	-0.37771
CF TSH	-2.1284	**-0.16959**
CF THA	-0.22368	**0.77967**
CT THH	**1.6576**	-0.18223

Source: Authors (2024)

According to the data presented in Table 5, it can be seen that the first main component (CP1) has greater weight for the sanitizing treatments MB THA, MB THH, XP THH, TQ THA, TQ THA, TQTHH and CT THH and the component main (CP2) presents greater weight MB TSH, XP TSH, XP THA, TQ TSH, CF TSH and CF THA.

Graph 01 presents the main components (CP1) and (CP2), displaying their respective weights, enabling a visualization of the main groupings in the set of variables.

Figure 01. Principal component analysis graph for sanitizing treatments of tomato samples.



Source: Authors (2024)

According to graph 1, it is possible to observe that treatment with 100 ppm sodium hypochlorite solution is related to the main component CP1 and presented the greatest reductions for total coliform microorganisms CT, thermotolerant coliforms CTT and Escherichia coli EC.

IV. Conclusion

The tomatoes sold in supermarkets and markets in the city of Paraíso do Tocantins had good biometric attributes with an average mass of 178.20 grams, an average transverse diameter of 72.46 millimeters and an average longitudinal diameter of 57.82 millimeters. The physicochemical evaluation showed average pH values of 4.34, titratable acidity of 0.24%, soluble solids of 5.81 brix, humidity of 94.94% and vitamin C of 11.27mg, revealing high levels of humidity, total soluble solids and average acidity values. Average counts of total coliforms equal to 1058 NMP/g, thermotolerant coliforms equal to 150.5 NMP/g, Escherichia coli equal to 13.15 NMP/g and absence of Salmonella sp. The treatment with 100 ppm sodium hypochlorite solution for 20 minutes reduced the amount of total coliforms by 97.91%, the amount of thermotolerant coliforms by 93.01% and the amount of Escherichia coli by 71%. The tomatoes sold in the city of Paraíso presented fruit within the physical-chemical and microbiological quality standards established by the legislation, so the tomatoes can be consumed after effective sanitization for fresh consumption, without risk to the health of the consumer, regardless of the establishment of purchase. Further research should be carried out to identify the fungi present in tomatoes, as well as monitoring to prevent outbreaks of food-borne diseases (FBD).

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