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Risk perception and sensory analyses of fresh tomatoes obtained from an open market in São Paulo, Brazil

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ABSTRACT

The nutritional and sensory qualities of tomatoes favor their acceptance worldwide. This study was carried out to evaluate the risk perception of agrochemical and sensory residue in tomato consumption. Thus, 12 kg of organic tomatoes (OT) and 12 kg of conventional tomatoes (CT) at an equal maturation stage were selected. R version 3.6.1 was applied to the analysis of physical and chemical variables. The Mann-Whitney test with a value of $p<0.05$ was used to verify associations between the groups. The sensory evaluation involved 37 volunteers and considered the mean answers of each question about the perception of fresh tomatoes. The OT presented about 13% more ascorbic acid in relation to CT, but there was no significant difference between them ($p>0.05$). OT detected higher values for pH, soluble solids (ºBrix) and titratable acidity, but there were no significant differences between them ($p>0.05$). Chlorfenapir residues below the Acceptable Daily Intake (IDA) value (0.03 mg/kg per capita) were detected, indicating a low risk of acute toxicity. Chlorfenapir is banned in Europe, but remains detected in Brazil. Public policies are needed to encourage sustainable food production.

Keywords: *Solanum lycopersicum*, safe food, horticulture, organic agriculture, chlorfenapyr.

RESUMO

Percepção de risco e análise sensorial de tomates frescos provenientes de feira livre em São Paulo, Brasil

A qualidade nutricional e sensorial favorece a aceitação do tomate no mundo todo. Realizou-se este estudo para avaliar a percepção de risco do resíduo agroquímico e sensorial do consumo de tomates. Desta forma, foram selecionados 12 kg de tomates de sistema orgânico (TO) e 12 kg de tomate convencional (TC), de igual maturação. Para análise das variáveis físicas e químicas aplicou-se o R versão 3.6.1. Para verificar associações entre os grupos empregou-se o teste de Mann-Whitney com valor de $p<0,05$. A avaliação sensorial envolveu 37 voluntários e considerou a média das respostas de cada questão sobre a percepção do tomate *in natura*. O TO apresentou cerca de 13% mais ácido ascórbico em relação ao TC, mas não houve diferença significativa entre si ($p>0,05$). O TO detectou valores maiores para pH, sólidos solúveis (ºBrix) e acidez titulável, mas não houve diferenças significativas ao TC. Detectou-se resíduos de clorfenapir abaixo do Valor da Ingestão Diária Aceitável (IDA) (0,03 mg/kg *per capita*), indicando baixo risco de toxicidade aguda. O clorfenapir proibido na Europa segue detectado no Brasil. São necessárias políticas públicas de incentivo à produção sustentável de alimentos.

Palavras-chave: *Solanum lycopersicum*, alimento seguro, horticultura, agricultura orgânica, chlorfenapyr.

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Tomato (*Solanum lycopersicum*, cv. Debora) is a very popular food, highly valued for its sensory quality and high nutritional value. It is classified as a functional food from its high concentration of lycopene, a carotenoid which, despite not having pro-vitamin A activity, has a direct protective effect against free radicals. In addition to lycopene, tomatoes are rich in vitamin C, vitamin E and β-carotene, which are important essential nutrients (Gürbüz Çolak *et al*., 2020). Tomatoes are the second most abundant agricultural product worldwide, and are one of the most consumed vegetables in Brazil, inserted in the group of vegetable foods that represent 30.86% of national consumption (ANVISA, 2019). Tomato crops are vulnerable and often attacked by various pests and diseases caused by bacteria, virus and fungi. Therefore, large amounts of pesticides are frequently applied in crops, which when used excessively or inappropriately leads to contamination with residues which affect the health of consumers with serious exogenous intoxication (Pignati *et al*., 2022).

Brazilian agricultural production imported about 1,550 thousand tons of agrochemicals in 2014, about 7.5 kilos of pesticides *per capita* per year. Since 2016, Brazilian economic policies have consumed one-fifth of all pesticides produced in the world (HRW, 2018). The use mainly occurs in the Midwest and South regions and in the state of São Paulo (Moraes, 2019).

The pesticide residues in fresh vegetables have been monitored for decades in most developed countries. However, they are not properly reported in developing countries (Elgueta *et al*., 2020). The use of unauthorized or indiscriminate pesticides can lead to the adherence of residues of these compounds to the product in a concentration above the maximum residue limit (MRL) (Andrade *et al*., 2021).

However, it is necessary that the vegetable does not present agrochemical residues above the values allowed by legislation for human consumption, having to meet food safety criteria (Asensio *et al*., 2019). The term food safety is defined by the General Principles of Food Hygiene of the Codex Alimentarius (FAO, 2003), as being food, which will not cause harm to consumers' health. Food safety depends on controlling physical, chemical, or microbiological hazards that may have occurred at some stage of production, processing and/or distribution. In a broader perspective, food safety refers to the guarantee and right of access to food for people around the world in appropriate amounts and nutritional values through the implementation of public policies.

In the current scenario of conventional agriculture, the highest crop yield is the result of genetic improvement and application of mineral fertilizers, herbicides, insecticides, acaricides, nematicides, fungicides and synthetic bactericides (Lang *et al*., 2012). High pesticide doses are frequently used in spraying tomatoes for pest and disease control to avoid damage (Mazzei *et al*., 2021), but this intensive food production model is considered unsustainable in different regions of the planet, with increasing evidence of impacts to the environment and human health, mainly due to the flow of fertilizers and pesticides into water sources, causing an accumulation of waste for human consumption (Lang *et al*., 2012).

The use of agrochemicals, as well as the consequences of their use, are classified as technological risks. For Beck (2011), risks of this nature must predict failures in the control system and consider a set of economic, political and social factors in their causality. Therefore, the effects of agrochemicals are global risks, and in turn, according to Beck (2011), they produce secondary effects of systems and modernization processes resulting from human actions and omissions.

A demand for legislation and regulatory frameworks has emerged, bringing a new cultural meaning of public concern about food-related risks to the forefront (Lang *et al*., 2012); major public policies have emerged in the last 40 years with the priority of managing and alleviating the most harmful effects of human and industrial activity on the environment, especially the impacts generated by the food supply chain in relation to the healthy state of the natural environment and of plant, animal, air, water and soil. To this extent, food has become one of the points of interconnection between human health and the environment (Lang *et al*., 2012).

Considering that risk perception due to contaminated foods of plant origin is one of the factors that motivates the global food safety crisis, this study was undertaken to investigate the level of contamination by agrochemical residues in fresh tomato fruits sold in open markets of the municipality of Diadema, SP, Brazil, and to evaluate the potential risks for consumers from the perspective of food safety. It addressed the following points: i) to compare tomatoes produced by conventional and organic crops regarding the contamination degree by agrochemical residues and also in relation to physical and chemical variables that indicate the nutritional quality of the products; and ii) to evaluate the sensory properties of the fruits (organic and conventional) with application of sensorial analysis by a group of voluntary consumers.

MATERIAL AND METHODS

Selection of tomatoes used in the study

Fresh tomatoes were obtained from different street markets located in the city of Diadema, São Paulo, Brazil, from October 2018 to February 2019. Fruits produced in an organic cultivation system (agricultural system in which only organic fertilizer is used and no pesticides are applied) and also conventional cultivation (agricultural system in which mineral fertilizers and pesticides are used) were selected; 12 kg of each with similar maturation time. After visiting the open markets, it was found that the tomatoes sold came from the Companhia de Entrepostos e Armazéns Gerais de São Paulo (CEAGESP). Half were destined for sensory analysis research; 6 kg each group. The other half (6 kg each) underwent physical-chemical analysis.

Sensorial analysis

Sensory analysis is an exploratory cross-sectional observational study. The survey on the sensory perception of tomato features was carried out with 37 volunteer participants on the premises of the Federal University of São Paulo (UNIFESP) in partnership with the Specialization course in Nutritional Education of the same educational institution. This study was approved by the Ethics Committed by *Plataforma Brasil* (CAAE: 91198618.8.0000.5505) prior to its commencement and all participants were informed about the research aims and signed an Informed Consent Form (ICF).

The research participants initially answered a sociodemographic questionnaire and tomato consumption habits:

Age; education; gender; occupation.

Tomato consumption frequency (daily, weekly, fortnightly and monthly); place of purchase; the criterion adopted for purchase; consumption/preparation method of tomatoes at home; method used for cleaning.

Evaluation of the sensory attributes of fresh tomatoes using a hedonic scale with five different points, with a scale of: 5: "Like very much"; and 1: "Dislike very much", for aroma; flavor; firmness; succulence; overall impression.

Based on the availability and frequency of consumption of tomatoes, consumers were invited to evaluate the sensory quality of fresh tomatoes produced in an organic system and also in a conventional system. Each taster received approximately 30 g of each sample in slices in a balanced full block design with multiple comparisons, with the samples served simultaneously and evaluated sequentially using white disposable cups coded with three-digit numbers. The tomatoes were properly sanitized in standardized sodium bicarbonate solutions to perform the analyses. Standardized tomato hygiene was used to remove traces of pesticides present in the tomato skin.

Physicochemical analysis of tomatoes

The OT and CT samples were submitted to physical and chemical analysis to determine the following variables: analysis of agrochemical residues, analysis of instrumental color, analysis of cross-section diameter and texture, analysis of pH, analysis of soluble solids, titratable acidity, and vitamin C.

A total of 12 fresh fruits were sent for each of the analyses, with the samples being crushed and homogenized at room temperature. All determinations were performed in triplicate and the results expressed as mean ± standard deviation.

Instrumental color analysis

The instrumental color of the tomatoes was measured on the surface of each fruit using a portable colorimeter (Konica Minolta, CR-400, Osaka, Japan) calibrated using a color standard (white) supplied by the manufacturer, with the following coordinates Y=92.7, x=0.3162 and y=0.3325. The instrument was standardized to operate with the following specifications: observation angle of 2° and illuminant C. The CIE L*a b* color space coordinates were obtained at three random positions on the surface of organic and common tomatoes.

Analysis of cross-section diameter and texture

Before carrying out the firmness test, the cross-section diameter of the fruits was measured using a universal caliper with fine adjustment (Mitutoyo Corporation, Tokyo, Japan). Tomatoes were cut longitudinally and each tomato half was evaluated for the firmness test (n=2). Tomato firmness was determined using a texturometer (Brokfield, CT3 Texture Analyzer, USA) according to the method described by Bourne (2002). The firmness test was used to simulate the compression performed by the consumer when purchasing tomatoes. A 36 mm diameter flat tip cylindrical head compressed the tested sample at a constant speed of 1 mm/s and to a depth of 10 mm.

pH analysis

The pH was determined by direct measurement in a Tecnal potentiometer, model TEC-5.

Analysis of soluble solids

The content of soluble solids (ºBrix) was evaluated by direct reading in a Hanna HI86801model digital refractometer, according to analytical standards described in Pregnolatto & Pregnolatto (1985).

Analysis of titratable acidity

The titratable acidity was determined by titration with 0.1 M NaOH and the results expressed as a percentage of citric acid (Zenebon *et al*., 2008).

Analysis to determine vitamin C

The content of vitamin C was determined using the titrimetric method based on the reduction of the indicator 2,6-dichlorophenolindophenol by ascorbic acid, with the results being expressed in mg of ascorbic acid per 100 mL of juice.

Analysis of agrochemical residues

The agrochemical residue analyzes were performed by the Laboratório Agrosafety Monitoramento Agrícola Ltda. (Protocol No. EA-AGS 720C/19-01-Rev00). A total of 384 substances were analyzed following the POPMET020-R09 and POPMET021-R09 methods (Lehotay, 2007).

Statistical analysis

The data were analyzed using the R version 3.6.1 statistical program (R Core Team, 2019) to evaluate the physical-chemical variables. The assessment of associations between groups was performed using the Mann-Whitney test, a non-parametric statistical test. The significance level was set at a value of $p<0.05$. The sensory tests were qualitatively and quantitatively evaluated considering the average of the answers for each question related to the perception of fresh tomatoes.

RESULTS AND DISCUSSION

Sensorial analysis of the tomatoes

The voluntary consumers who participated in the present study did not differentiate the sensory attributes between OT and CT samples (Table 1). Both samples generally received scores between 4 and 5 for all investigated variables, indicating good acceptance.

It is important to investigate the sensory attributes, as the choice of fresh tomatoes by the consumer is mainly influenced by visual appearance, texture, pulp firmness, flavor and taste (Oltman *et al*., 2016).

The sugar and acid contents are the most important attributes to evaluate the sensory quality of the tomato. pH is one of quality parameters of fruit which represents acidity level and is used as a taste indicator. Fruits experience physiological changes during ripening which involve starch being converted to sugars, flavor formation, and increased pH (Wati *et al*., 2021).

However, choosing tomatoes only based on sensory perceptions does not guarantee safety for consumption, particularly the presence of agrochemical residues in the product (i.e. if the producer has respected the recommended dose of the pesticide and the adequate time between application and the crop harvest). Therefore, it is important to invest in public policies in all administrative spheres to guarantee regulatory measures on the application of pesticides, both to protect the health of rural workers, the health safety of final consumers and also for environmental protection in order to avoid contamination of soil and water (Lang *et al.*, 2012).

The sensory scores attributed by consumers to CT and OT were generally consistent with the trends described in the physical-chemical analyses, in which no differences were observed between the samples.

Instrumental color, cross-section diameter and tomato firmness

The instrumental color of the OT and CT samples, as expressed through the L* (luminosity), a* (red) and b* (green) coordinates, did not vary significantly (p>0.05), as shown in Table 2. The evaluated samples were classified as red ripe according to tomato color, depending on its maturation stage, with more than 90% of the surface being red. Tomatoes have an oblong shape, meaning a greater longitudinal diameter than cross-sectional, which is characteristic of the Debora cultivar. The cross-section diameters of the tomatoes did not differ from each other.

OT samples were classified as medium-class or medium-sized tomatoes according to the largest cross-section diameter (58-60.8 cm) of the tomato in relation to the longitudinal diameter, while conventional tomatoes were classified as large-class or large-sized tomatoes (normative instruction no. 33, of July 18 by MAPA (Brasil, 2018). However, this difference in the cross-section diameter of the tomatoes did not reflect differences in the texture (firmness test) of organic and conventional tomatoes (p>0.05), indicating that they had the same ripening stage. Firmness is also one of the main quality attributes of tomatoes for salads at the time of purchase (Oltman *et al.*, 2016).

Chemical properties indicative of the nutritional quality of the tomato

The OT presented about 13% more vitamin C (ascorbic acid) in relation to the tomato produced by conventional agriculture, but they did not present significant differences between them (p>0.05), according to Table 3. The organic tomato also showed higher values for pH, soluble solids (ºBrix) and titratable acidity, but these differences were not significant in relation to conventional tomatoes (Table 3).

The pH of the tomato samples evaluated in the present study corresponded to the pH values of ripe tomatoes found in the specialized literature, which ranges from 4 to 4.5, and these values tend to decrease with its dehydration (Borguini & Silva, 2005). The organic tomato had a higher total soluble solid content than the conventional tomato, probably due to the higher vitamin C and sugar content. The value of soluble solids identified in the two groups of tomatoes evaluated in this study are in accordance with what is indicated in the literature for the cultivar, with values ranging from 3.5 to 5.5ºBrix. Most tomato cultivars produce fruits ranging from 5 to 7ºBrix. However, the percentage of total soluble solids in organic and conventional tomatoes in the present study was higher than those found in Debora cultivar tomatoes (4.48 and 3.93°Brix, respectively) evaluated by Miguel *et al.* (2007). Of the total soluble solids contained in tomatoes, about half is composed of sugars and 1/8 of acids, with the predominant sugars being glucose and fructose and the predominant acid being citric (Ferreira *et al*., 2006). The soluble solids content is mainly related to the sugars and acids present in the fruit, and these components reflect the sensory quality and the consumer's preference for its flavor (Azodanlou *et al*., 2003).

Analysis of agrochemical residues in tomatoes

No agrochemical residues were identified in the OT samples, while only chlorfenapyr residue (4-bromo-2-(4-chlorophenyl)-1-ethoxymethyl-5-(trifluoromethyl)pyrrole-3-carbonitrile) was found in the CT samples in a value equal to its minimum limit of quantification (i.e. 0.01 mg/kg). This active ingredient is used as insecticides and acaricide in foliar applications in tomato crops, with a maximum residue limit (MRL) equal to 0.2 mg/kg, with a safety interval of 7 days. Chlorfenapyr belongs to the chemical group of Pyrrole; it is a contact insecticide and acaricide, toxicological classification III (medium toxic) and with potential for environmental hazard II, considered as a very dangerous product for the environment (IBAMA, 2020).

Chlorfenapyr application in tomato cultivation is mainly aimed at controlling pests which have become resistant to repeated application of products based on organophosphates, carbamates and pyrethroids (Patra *et al*., 2018). The chlorfenapyr values found in the samples of the present study remained below the ADI value (0.03 mg/kg per capita) recommended by ANVISA (2020), indicating a low risk of acute toxicity. However, it is important to note that chlorfenapyr is an active prohibited use in many countries, for example throughout the European Union, although its use is authorized in Brazil (IBAMA, 2020). According to ANVISA (2019), the active ingredient chlorfenapyr is one of the most detected pesticides in plant food samples in Brazil, occupying the 15th position.

According to Mazzei *et al.* (2021), the tomato plant is very susceptible to pests and diseases, and therefore

Table 1. Sensory scores (mean ± standard deviation) to organic and conventional tomato samples (*Solanum lycopersicum*, cv. Debora) during sensory analysis. Diadema, UNIFESP, 2019.

Cultivation system	Aroma	Flavor	Firmness	Succulence	Overall impression
Organic	3.8± 0.92[a]	3.8±1.06[a]	3.9±0.85[a]	4.0±0.98[a]	3.9±0.96[a]
Conventional	4.0±0.97[a]	3.6±1.09[a]	4.0±0.97[a]	3.9±1.01[a]	3.8±1.03[a]

*Hedonic scale with five different points, where 5: "Like very much" and 1: "Dislike very much". Different letters in the same column indicate a significant difference (Mann-Whitney, p<0.05).

different pesticides are used throughout the crop cycle in order to control such infestations and guarantee their productivity. However, inadequate management of pesticides causes contamination of vegetables, soil, groundwater and water bodies. The indiscriminate use of agrochemicals in crops has become the subject of many debates promoted by civil society in recent years, since consumers have become more interested in the safety of the vegetables they consume, especially in relation to the presence of possible pesticide residues. Abd-Elhaleem (2020) points out that pesticide toxicity can be fatal to living beings, and the severity of contamination depends on the active ingredient of the product, the concentration and the exposure route to the contaminant. Thus, identifying the active ingredient of the pesticide and the concentration of its residues in food is very important for the safety of human health.

Although the analysis of pesticide residues in CT samples purchased at open markets in Diadema, SP is within food safety parameters, this fact does not guarantee that the consumer is free from contamination by pesticide residues when buying fresh fruits at other commercial points or other times of the year. In a survey carried out by ANVISA (2019), 316 samples of table tomatoes were analyzed and only 12% of the total did not show pesticide residues, with 52% showing values equal to or below the MRL and 36% were considered unsatisfactory. Furthermore, 45 different types of pesticides were detected among the evaluated samples, with the most representative being imidacloprid, fenpropathrin and carbendazim (ANVISA, 2019). There are currently 2,854 records of pesticides in Brazil, and 51 products were registered only in the first quarter of 2022, of which 44 are intended for tomato cultivation (Brasil, 2022). Regarding the classification of registered products which pose environmental risks, about 2.9% are class I (highly dangerous to the environment), 44.6% are class II (very dangerous to the environment), 33.7% are class III (dangerous to the environment), 18.5% are class IV (little dangerous to the environment) and only 0.3% offer low risk to the environment.

Table 2. Cross-section diameter, firmness and instrumental color (CIEL*a*b*) of organic and conventional tomato samples (*Solanum lycopersicum*, cv. Debora). Diadema, UNIFESP, 2019.

Cultivation system	L*	*a**	*b**	Cross-section diameter (mm)	Firmness (N)
Organic	38.3±0.04 [a]	20±0.3 [a]	22.6±0.6 [a]	58.0± 0.5 [a]	3.9±0.2[a]
Conventional	39.0±0.4 [a]	21±0.3 [a]	24.2±0.5 [a]	60.8± 0.5 [a]	4.0±0.2 [a]

Different letters in the same column indicate a significant difference (Mann-Whitney, p<0.05).

In view of the above, we can see the importance of greater investment in more studies on this research line, which should be conducted in other regions of the country, since fresh tomatoes are of great importance for the Brazilian diet and correspond to about 3.78% of the daily per capita acquisition percentage in the country (ANVISA, 2019). The need for a broad safety policy in food production is evident, considering conservationist production methods that make rational use of natural resources.

The results of this work suggest equivalence between the physicochemical, sensorial and agrochemical properties of organic and conventional tomatoes sold in street markets in the city of Diadema, SP, Brazil. Tomatoes are fully established in Brazilian food behavior and can be considered safe from the point of view of human consumption; however, it is impossible to assess the impacts that the use of agrochemicals triggers on water, soil, biodiversity and food sovereignty through this study.

Food policy encompasses the collective efforts of governments to influence the decision-making environment of food producers, consumers and marketers in order to promote food safety. In this scenario, one can see the importance of greater investments in research on food safety, as they contribute to promoting public policies aimed at conservationist agricultural production and ecological health. Greater efforts are needed on the part of governments to educate rural producers on the use of pesticides and also to supervise the handling of inputs in the field in order to guarantee safe products for society's consumption.

Even though the commercialization of organic products has increased in recent years, prices are often higher than those of vegetables produced in conventional systems, making the purchase unfeasible by the majority of the Brazilian population, and constitutes a factor which triggers elitism of organic products in some regions.

It is noticed that the search for compliance with environmental ethics, in some cases, increases the acquisition of organic vegetables by only a small portion of the population due to the price of these products. Organic tomatoes had much higher prices on average than their conventional counterparts; this difference is justified by the cultural practices of maintaining pest and disease control in the crop and guaranteeing productivity without the use of agricultural inputs from non-organic sources, such as mineral fertilizers, herbicides, insecticides, fungicides, bactericides and acaricides.

Table 3. Results of chemical analyzes (mean ± standard deviation) related to the nutritional quality of organic and conventional tomato samples (*Solanum lycopersicum*, cv. Debora). Diadema, UNIFESP, 2019.

Cultivation system	pH	Soluble solids (ºBrix)	Titratable acidity (%)	Vitamin C (mg/100mL)
Organic	4.47 ± 0.04[a]	5.10 ± 0.10[a]	0.52 ± 0.01[a]	37.25 ± 1.61[a]
Conventional	4.38 ± 0.03[a]	4.33 ± 0.06[a]	0.47 ± 0.02[a]	32.59 ± 1.61[a]

Different letters in the same column indicate a significant difference (Mann-Whitney, p<0,05).

In addition, another relevant factor to be considered in this context is the advertising and competitive exploitation using the organic certification as a guarantee of sustainability, but without considering the general context of food safety which involves guaranteeing access to basic and quality foods for the entire population, without compromising access to other essential goods and services for maintaining a healthy life.

Public policies from the point of view of food safety are needed to propose legislation, to promote the practices of organic agriculture and to require a technical officer to guide and supervise trade in commercial agrochemical establishments. Proposing quality control policies for production methods can minimize consumers' perception of risk, in addition to relieving them of the responsibility for selecting good quality foods. Public policies which favor access to fresh food can contribute to reducing social inequality and food insecurity in the countryside and in the urban context.

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