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Tomato waste extract (*Lycopersicon esculentum*) as a natural antioxidant in soybean oil under heating

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Highlights: The paper addresses the stability of bioactive in soybean oil and is important because it evaluates the use potential of tomato waste extract as. Natural antioxidant in vegetable oils.

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ABSTRACT - The tomato processing industry generates a large amount of waste, usually composed of peels and seeds. It is known that the tomato is rich in bioactive compounds, mainly carotenoids (lycopene and β-carotene), however, studies on the functionality of its residues are scarce. Thus, these residues are discarded without the knowledge of possible antioxidant potential. The objective of this work was to determine the stability of bioactive in soybean oil added to the extract of agroindustrial tomato waste under heating. The extract obtained with ethyl alcohol at the ratio of 1: 5 (w/v) was initially analyzed for total phenolic compounds, lycopene, β-carotene, and antioxidant activity using the DPPH and β- carotene / linoleic acid. Subsequently, the extract and the synthetic antioxidants, butylhydroxytoluene (BHT) and tert-butylhydroquinone (TBHQ) were applied in

soybean oil, and the treatments subjected to heating in Rancimat (180ºC/5 h). The thermoxidated samples were analyzed for the composition of tocopherols by high-performance liquid chromatography (HPLC), phytosterols, and fatty acid profile by gas chromatography (GC). The extract of agro-industrial tomato residues showed moderate results concerning its antioxidant activity, 68% by the DPPH method, and 26.2% of auto-oxidation of the β-carotene / linoleic acid system. The synthetic antioxidant TBHQ had a greater protective effect on soybean oil when compared to the control, providing greater retention of phytosterols (85%) and tocopherols (93%). Tomato extract can be used as a natural antioxidant in industrialized oils, but with less effectiveness than the antioxidant TBHQ.

Keywords: Vegetable oil; Bioactive compounds; Antioxidants.

INTRODUCTION

The economic growth of the population and changes in dietary habits have caused a diet rich in complex carbohydrates and fibers to be replaced by foods with a high proportion of fats and saturated fatty acids. Lipids have great importance for the human diet, constituting the largest source of caloric energy for the body. Despite this, their behavior, metabolism, and functions are much studied because of the various health implications (Szydłowska-Czerniak, Dianoczki, Recseg, Karlovits, & Szłyk, 2008).

Oils and fats are subject to several reactions that result in changes in their functional, sensory, and nutritional quality (O'Brien, 2007). Among these reactions, lipid oxidation is one of the main causes of food spoilage, since it is responsible for losses of essential fatty acids and is related to the safety of vegetable oils through the formation of toxic compounds (Chaiyasit, Elias, McClements & Decker 2007).

The delay or prevention of lipid oxidation can be accomplished by the addition of antioxidants. They are substances that inhibit oxidative reactions during storage, processing, and use of oils and fats and can be classified according to their origin in natural or synthetic (Ramalho & Jorge, 2006).

Several synthetic antioxidants can be added to the oils to protect them from oxidation, such as butyl hydroxyanisole (BHA), butylhydroxytoluene (BHT), and tert-butylhydroquinone (TBHQ). However, there is a strong tendency to substitute synthetic antioxidants for natural antioxidants, since research has shown the possibility of synthetics presenting toxic effects (Chen, Rao, Ding, McClements & Decker, 2016).

The finding that plants have biologically active substances that bring health benefits or desirable physiological effects has boosted studies on their antioxidant property (Jiménez-Zamora, Delgado-Andrade, Rufián-Henares, 2016). In the use of natural antioxidants, there is an advantage also in the preservationist level, insofar as the food industries produce wastes that could have a much more beneficial destiny, favoring the man and the environment (Trivellini *et al.,* 2016).

Brazil is one of the countries that produce the most agro-industrial waste. The main wastes generated in the processing of fruit pulps are, depending on the type of processed fruit, bark, core or seed, and bagasse. Although often discarded, this material can be used as a natural source of macronutrients and bioactive compounds (Silva & Jorge, 2014a). This is the case of the waste generated by the tomato used for the preparation of juices, purees, pulps, ketchup, soups, etc.

In view of the above, the main objectives of the present work were to analyze the stability of bioactive compounds in soybean oil added to the extract of agroindustrial tomato waste (*Lycopersicon esculentum*) submitted to heating.

MATERIAL AND METHODS

Oil

For this work, refined soybean oil, without the addition of synthetic antioxidants (TBHQ and citric acid), processed by Triângulo Alimentos S/A, Itápolis-SP, Brazil, was used.

Agroindustrial waste of tomato

The tomato waste, composed of seeds and husks, was collected in the Predilecta industry, located in Matão-SP, Brazil. About 15 kg of waste were placed in a plastic bag and transported at room temperature to the place of analysis. The immersion of the waste in water allowed the separation of seeds and bark remains by density difference. The tomato waste originated from the production of concentrated pulp, which involves a heat treatment between 80 and 90°C, whose purpose is the enzymatic inactivation and peeling of the fruit.

After separation, all seeds were submitted to a cleaning process to remove sugars and other interferents. The seeds were placed in sieves and washed with running water until removal of the visibly present pulp wastes. Soon they were given another bath with distilled water. The seeds were dried in an air circulation oven (Marconi, model MA 035) at 40°C. The drying time was established until the seeds reached a humidity of less than 10%, ranging from 1 to 7 days, depending on the size of the seeds. After drying, they were packed in glass vials, sealed with a screw cap, protected from light, properly labeled, and stored at room temperature.

Obtaining of extract

To obtain the extract, the ground agri-industrial waste (20 g) was kept under permanent stirring with ethanol (100 mL) at room temperature (25 ± 2°C) for 30 minutes, and then the mixture was filtered and the supernatant submitted to rotary evaporator under reduced pressure at 40°C to remove the solvent used to extract the extract. The dried extract was weighed and resuspended in ethanol, yielding a stock solution containing 1 g of extract for each 10 g of ethanol solvent (1:10), used for direct applications in soybean oil.

Thermal oxidation

The following treatments were submitted to thermoxidation: soybean oil without addition of synthetic antioxidants and citric acid (SO), soybean oil with the addition of 100 mg/kg of TBHQ (TBHQ), soybean oil with the addition of 100 mg/kg of BHT and soybean oil with the addition of 100 mg/kg of tomato waste extract (TWE). The treatments were compared with soybean oil-free synthetic antioxidants and citric acid and without heating (Control). In this assay, the treatments were thermoxidized in Rancimat, using 10 g of oil at 180°C and continuously for 5 hours. After heating, the samples were conditioned in amber flasks, inert with nitrogen gas, and stored under refrigeration until the analysis.

Extract analysis

Quantification of total phenolic compounds was determined by spectrophotometry using the Folin-Ciocalteu reagent described by Singleton & Rossi (1965). In this procedure, 100 µL of the ethanolic extract solution was pipetted into test tubes and 500 µL of the Folin-Ciocalteu reagent was added. Then, 1.5 µl of 20% saturated sodium carbonate solution and 6 ml of distilled water were added. This mixture remained at rest for 2 hours at room temperature and the absorbance was determined at 765 nm. For the quantification, a calibration curve was made, using gallic acid in concentrations of 0 to 500 mg/L. The coefficient of determination of the analytical curve was R^2 = 0.99. The contents of total phenolic compounds were expressed as mg equivalents of gallic acid per gram of extract (mg GAE/g).

The content of lycopene and β-carotene was determined according to the method proposed by Nagata & Yamashita (1992). Initially, the ethanolic extract (100 mg) was stirred for 1 minute with 10 mL of an acetone-hexane (4: 6) mixture and filtered with the aid of filter paper. The filtrate was then subjected to spectrophotometer reading at different wavelengths (453, 505, 645, and 663 nm). The contents of lycopene and β-carotene were calculated according to the following equations: lycopene (mg/100 mL) = $-0{,}0458\ A_{663} + 0{,}372\ A_{505} - 0{,}0806\ A_{453}$; β-carotene = $0{,}216\ A_{663} - 0{,}304\ A_{505} + 0{,}452\ A_{453}$. The assays were performed in triplicate and the results were expressed as mg of carotenoid / g extract.

The antioxidant content by the DPPH free radical method was determined according to the

methodology described by Brand-Williams *et al*. (1995). In this procedure, an ethanol solution of 100 µg/mL of agroindustrial waste extract was prepared. Each sample of this solution (0.3 mL) was added to 2.7 mL of DPPH solution (40 µg/mL) at different concentrations (5, 10, 25, 50, 125 and 250 µg/mL). A control with 2.7 mL of DPPH and the blank with 0.3 mL of ethanolic solution of the extract and 2.7 mL of ethanol were also made for each concentration. After the reaction time of 30 minutes, the absorbance was read at 515 nm and converted to the percentage of antioxidant activity (AA) by the following Eq. (1):

$$AA\ (\%) = 100 - \{[Abs_{Sample} - Abs_{white}) \times 100] / Abs_{control}\} \quad (1)$$

Where Abs = absorbance.

The antioxidant capacity measured by the β-carotene / linoleic acid system was obtained according to the method developed by Marco (1968) and modified by Miller (1971), in which linoleic acid, Tween 40 and β-carotene were used in chloroform. This system was maintained at approximately 50°C, the absorbance measured at 470 nm at 15 minutes intervals for 2 hours and the result expressed as a percentage of antioxidant activity (AA) by the following Eq. (2):

$$AA\ (\%) = \{[(Abs_{b\ initial} - Abs_{b\ end}) - (Abs_{a\ initial} - Abs_{a\ end}] / (Abs_{b\ initial} - Abs_{b\ end})\} \times 100 \quad (2)$$

Where Abs_b = absorbance of white and Abs_a = Sample absorbance.

Oil analysis

The composition of phytosterols was determined by gas chromatography with previous saponification of the sample. Saponification was performed according to Duchateau *et al.* (2002). For the determination of the phytosterols content, the Ch 6-91 method of AOCS (2009) with adaptations was used. The analysis was performed in a gas chromatograph (Shimadzu, Chiyoda-ku, Tokyo, Japan), model Plus-2010, with flame ionization detector, split injector, and automatic sampler. Analysis conditions: 30 m long fused silica capillary column (Restek RTX 5, Shimadzu, Chiyoda-ku, Tokyo, Japan) with an internal diameter of 0.25 mm and film thickness of 0.25 µm. The column temperature programming was 100oC for 2 minutes, heated at 15ºC/min to 260ºC, and maintained in isotherm for 35 minutes. The temperatures used on the injector and detector were 280 and 320°C, respectively. The drag gas used was hydrogen with a linear velocity of 40 mL/min. Phytosterols were identified by comparison with the retention time of the pure standards analyzed under the same conditions as the samples. The quantification of each isomer was performed by internal standardization (β-cholestanol = 5α-cholestane-3β-ol, 95% purity) based on peak areas using cholesterol, campesterol, stigmasterol, β-sitosterol and stigmastanol (Supelco, Bellefonte, USA) having a purity of 99, 99, 95, 98 and 97.4% respectively. The individual phytosterols contents were expressed as mg per 100 g oil (mg/100 g).

The tocopherols content was determined using the method of Ce 8-89 of AOCS (2009). The analysis was performed by CLAE (Varian Inc., Walnut Creek, Ca, USA), model 210-263, with a fluorescence detector. Analysis conditions: 250 x 4.6 mm silica packed with silica (Microsorb 100 Si, Varian Inc., Walnut Creek, Ca, USA) column with 0.5 µm pore and excitation wavelength at 290 nm and emission at 330 nm. Chromatographic separation was performed by isocratic elution of mobile phase consisting of n-hexane: isopropyl alcohol (95.5:0.5 v/v) with a flow rate of 1.2 mL/min. Tocopherols were identified by comparison with the retention time of the pure standards analyzed under the same conditions as the samples. The quantification of each isomer was performed by external standardization based on peak areas, using standards of α-, β-, γ- and δ-tocopherol (Supelco, Bellefonte, USA) with 99.9, 98, 0, 99.4 and 99.6%, respectively. The individual tocopherol contents were expressed as mg per kg of oil (mg/kg).

The fatty acid composition of the samples was determined by gas chromatography with prior esterification of the samples. The methyl esters of the fatty acids present in the oils were obtained according to the procedure described by Ce 2-66 of AOCS (2009). 0.1 g of oil, filtered over anhydrous sodium sulfate, was weighed into a test tube. After, 3 ml of n-hexane and 0.5 ml of 0.5 N potassium

methanolic hydroxide solution were added. Then it was stirred vigorously for one minute in vortexing and centrifuged for five minutes at 3000 rpm.

Already for the determinations of the fatty acids was used the method Ce 1-62 of AOCS (2009), with adaptations. The analyzes were carried out in Varian (Walnut Creek, USA) gas chromatograph, model CG 3900, equipped with flame ionization detector, split injector, and automatic sampler. The compounds were separated on a 60 m long CP-Sil 88 fused silica capillary column with an internal diameter of 0.25 mm and a film thickness of 0.20 µm. The column temperature programming was started at 90ºC for 4 minutes, heated at 10ºC/min to 195ºC, and maintained in isotherm for 16 minutes. The temperatures used in the injector and detector were 230 and 250ºC, respectively. The samples were injected in a volume of 1 µL, adopting the division ratio of 1:30. The entrainment gas was hydrogen with a linear velocity of 30 mL/min. Fatty acids were identified by comparing the retention times of pure methyl esters of fatty acids with the separate components of the samples and quantification was done by area normalization (%). A mixture of 37 fatty acid methyl esters (Supelco, Bellefonte, USA), C4:0 to C24:1, was used as the standard in purity between 99.1 and 99.9%.

Statistical analysis

The results of the analytical determinations, in duplicate, were submitted to analysis of variance to determine the influence of the treatments on the alteration of the oils submitted to the heating. For all determinations, analysis of variance and Tukey's test for averages at 5% were obtained through the STATISTICA version 7.0 program.

RESULTS AND DISCUSSION

Extract analysis

The yield of an extract and the identification of its bioactive compounds in natural sources, such as fruits, seeds, and spices, depending on the type of solvent used (Gil-Chávez *et al*., 2013). The percentage yield of the extract of tomato waste obtained after the removal of the ethanol used in the extraction process was 58.7% (Table 1).

Table 1. Yield, contents of phenolic compounds, total carotenoids, and antioxidant activity of the extract of tomato waste.

Yield (%)	58.7
Phenolic compounds (mg GAE/kg)	10.9 ± 2.4
Carotenoids	
Lycopene (µg lycopene/100 g)	6.8 ± 1.1
β-carotene (µg β-carotene/100 g)	12.1 ± 0.8
Antioxidant activity	
DPPH* (%)	68.0 ± 0.3
β-carotene/linoleic acid (%)	26.2 ± 12.5

Means ± standard deviations of the analyses performed; mg GAE/kg - Milligram Gallic Acid Equivalent per kilogram; µg lycopene/100 g - microgram lycopene per 100 grams; µg β-carotene/100 g - microgram β-carotene per 100 grams; *2,2-diphenyl-1-picrylhydrazyl radical free radical assay.

One of the main aspects related to the antioxidant effect of tomatoes is the presence of phenolic compounds. According to Table 1, the concentration of total phenolic compounds found in the extract was 10.9 mg GAE/kg, a result inferior to that obtained by Fuentes *et al.* (2013) for tomato seed extract.

The tomato is considered a fruit of high antioxidant potential because it has in its composition the carotenoid lycopene (Martinez-Valverde *et al*., 2002). Lycopene is the major carotenoid present in tomatoes, accounting for > 80% of the total tomato carotenoids (Stajcic *et al*., 2015). The mean lycopene content obtained in the present study (6.8 µg/100 g) was much lower than the value found by Kalogeropoulos *et al.* (2012) for tomato wastes (41.3 µg/100 g).

Although lycopene is the predominant carotenoid in tomatoes, β-carotene is also present in

this fruit, but lower concentrations. Kalogeropoulos *et al.* (2012) they found 14.9 µg β-caroteno/100 g in tomato waste, whereas in the present work only 12.1 µg β-caroteno/100 g.

The low contents of lycopene and β-carotene can be explained by the fact that the material used in this work consists mostly of seeds since it was initially immersed in water to separate the peels and pulp from the tomato. According to Borguini & Torres (2009) lycopene, like other carotenoids, is found in larger quantities in the bark of food, increasing considerably during its maturation. The importance of the bark for the carotenoid contents was also observed by Oliveira *et al*. (2009) since in its study the incorporation of the tomato peel into refined oil caused an increase in the concentration of β-carotene and lycopene when compared to the pure tomato pulp.

The antioxidant activity of the extract was determined using different methods. The DPPH radical method consists of a methodology that allows the evaluation of the antioxidant behavior of the compounds through the ability to sequester free radicals at a certain time. For this method, the antioxidant activity of the extract was 68% (Table 1).

In the DPPH method, the antioxidant activity is strongly associated with the phenolic compounds content, which explains the moderate values found for both analyses (Castelo-Branco & Torres, 2011).

Table 1 also shows the percentage value of antioxidant activity by the auto-oxidation method of the β-carotene / linoleic acid system. The extract under study presented 26.2% of antioxidant activity, lower value than that found by the DPPH method. According to Çelik, Ozyürek, Güçlü & Apak (2010), the variation of the expression of the antioxidant activity by these different methods suggests that the phenolic compounds of these wastes exert antioxidant activities by different mechanisms of action depending on the polarity of the reaction medium.

Melo *et al*. (2006) evaluated the antioxidant property of usually consumed vegetables. Moderate antioxidant action (60-70%) was exhibited by extracts of smooth lettuce, white onion, and cauliflower, while those of chuchu, carrot, cucumber, tomato, and pod showed less than 60% activity, considered as low antioxidant action.

Oil analysis

Phytosterols are the constituents that are present in the unsaponifiable fraction of plant matter. Most vegetable oils contain 100 to 1,500 mg/100 g of oil, with β-sitosterol being present in a larger quantity (Singh, 2013). Of the isomers evaluated in this study, β-sitosterol was also the sterol found in greater quantity, that is, 91.1% of total phytosterols for Control (Table 2). Before heating, the soybean oil used during that study had 321.9 mg/100 g of total phytosterols.

One way to monitor the quality of heated oils is to determine the concentration of antioxidants in oils, especially tocopherols, which are used to prevent lipid oxidation, improving stability (Kamal-Eldin & Appelqvist, 1996).

Table 2. Content of phytosterols and tocopherols of the soybean oil without heating.

Analysis	Control
Phytosterols (mg/100 g)	
Campesterol	14.8 ± 0.2
Stigmasterol	13.8 ± 0.0
β-sitosterol	293.3 ± 0.1
Total	321.9 ± 0.3
Tocopherols (mg/kg)	
α-tocol	71.7 ± 0.1
γ-tocol	379.5 ± 0.2
δ-tocol	77.3 ± 0.4
Total	528.5 ± 0.0
Vitamin E*	136.5 ± 0.2

*Expressed as UI/kg – Unit International per kilogram; mg/100g – milligrams per 100 grams. mg/kg – milligrams per kilogram.

According to Passotto *et al*. (1998), soybean oil has significant amounts of total tocopherols, considered potent natural antioxidants. In this study, soybean oil had 528.5 mg/kg of total tocopherols, with γ-tocol with 379.5 mg/kg.

Table 3 shows that the results differed significantly ($p < 0.05$) between the treatments, showing the influence of the different antioxidants on the composition in phytosterols after 5 h of heating at 180ºC.

Table 3. Content of phytosterols and tocopherols of the soybean oil without and with antioxidants heated at 180ºC/5 h.

Analysis	Treatments			
	SO	TBHQ	BHT	TWE
Phytosterols (mg/100 g)				
Campesterol	11.7 ± 0.4^{bc}	12.7 ± 0.0^{a}	11.4 ± 0.6^{c}	12.1 ± 0.0^{b}
Stigmasterol	13.3 ± 0.2^{b}	14.8 ± 0.0^{a}	12.5 ± 0.0^{c}	13.1 ± 0.2^{b}
β-sitosterol	226.7 ± 0.0^{c}	245.9 ± 0.1^{a}	226.8 ± 0.0^{c}	227.9 ± 0.1^{b}
Total	251.7 ± 0.2^{c}	273.4 ± 0.0^{a}	250.8 ± 0.6^{d}	253.0 ± 0.0^{b}
Tocopherols (mg/kg)				
α-tocol	56.1 ± 0.1^{c}	60.0 ± 0.0^{a}	55.8 ± 0.1^{d}	56.6± 0.1^{b}
γ- tocol	332.4 ± 0.2^{b}	358.7 ± 0.4^{a}	332.8 ± 0.2^{b}	334.1 ± 0.1^{b}
δ-tocol	70.6 ± 0.4^{b}	73.5 ± 0.5^{a}	71.2 ± 0.1^{b}	73.6 ± 0.4^{a}
Total	459.0 ± 0.7^{c}	492.0 ± 0.8^{a}	459.7 ± 0.1^{c}	464.2 ± 0.4^{b}
Vitamin E*	112.3 ± 0.2^{c}	120.5 ± 0.0^{a}	112.0 ± 0.1^{c}	113.0 ± 0.0^{b}

Means ± standard deviations of the analyses performed in duplicate followed by lowercase letters in the rows do not differ by Tukey test ($p > 0.05$). *Expressed as (IU/kg). SO (soybean oil), TBHQ (soybean oil + TBHQ, Extract (soybean oil + BHT), TWE (soybean oil + tomato waste extract). mg/100g – milligrams per 100 grams. mg/kg – milligrams per kilogram.

It was found that soybean oil added to TBHQ had the best retention of phytosterols (85%) when compared to Control, whereas BHT and TWE treatments showed a greater loss (22%). With heating, the SO suffered a loss of 22% of total phytosterols, as shown in Table 3.

The retention of tocopherols in soybean oil is one way of evaluating the efficiency of extracts added to the oil during accelerated storage and comparing them with the synthetic antioxidants (Silva & Jorge, 2014b).

Table 3 shows that the content of these compounds decreased with heating, presenting a significant difference ($p < 0.05$) between the treatments. It is observed that there was a loss of more than 13% of total tocopherols to SO when compared to Control (Table 2).

Among the antioxidants studied, it was observed that TBHQ presented the highest protective effect on total tocopherols, with retention of 93% after heating. The added oil of TWE was the second that presented a better protective effect on the tocopherols, with 88% retention after the heating. BHT and SO did not present a significant difference ($p > 0.05$), with higher losses for tocopherols.

Among the analyzed isomers, the values decreased in the following order: γ-tocol> δ-tocol> α-tocol for all treatments studied.

The proportion between saturated, monounsaturated, and polyunsaturated fatty acids is of great importance because vegetable oils with a high amount of polyunsaturated fatty acids are more susceptible to oxidative reactions when compared to those with the highest amount of saturated fatty acids (Lolos *et al*., 1999).

Table 4 shows that the soybean oil added to TBHQ had higher saturated and monounsaturated contents and lower polyunsaturated content, presenting significant differences ($p < 0.05$) with the other treatments.

Table 4. Fatty acid composition of the soybean oil without and with antioxidants heated at 180 ºC/5 h.

Fatty acid (%)	Treatments			
	SO	TBHQ	BHT	TWE
Saturated	16.8 ± 0.0^{b}	17.0 ± 0.1^{a}	16.8 ± 0.6^{b}	16.7 ± 0.0^{b}
Palmitic C16:0	11.7 ± 0.0^{a}	11.7 ± 0.1^{a}	11.6 ± 0.1^{b}	11.6 ± 0.0^{b}
Stearic C18:0	4.1 ± 0.0^{b}	4.2 ± 0.0^{a}	4.1 ± 0.0^{b}	4.1 ± 0.0^{b}
Arachidic C20:0	0.4 ± 0.0^{a}	0.4 ± 0.0^{a}	0.4 ± 0.0^{a}	0.3 ± 0.0^{b}
Behenic C22:0	0.4 ± 0.0^{a}	0.4 ± 0.0^{a}	0.4 ± 0.0^{a}	0.4 ± 0.0^{a}
Lignoceric C24:0	0.3 ± 0.0^{a}	0.3 ± 0.0^{a}	0.3 ± 0.0^{a}	0.3 ± 0.0^{a}
Monounsaturated	24.2 ± 0.1^{b}	24.5 ± 0.1^{a}	24.1 ± 0.6^{c}	24.2 ± 0.0^{b}
Oleic C18:1	23.6 ± 0.1^{bc}	23.9 ± 0.1^{a}	23.5 ± 0.1^{c}	23.7 ± 0.0^{b}
Eicosenoic C20:1	0.6 ± 0.0^{a}	0.6 ± 0.0^{a}	0.6 ± 0.0^{a}	0.6 ± 0.0^{a}
Polyunsaturated	59.0 ± 0.1^{a}	58.5 ± 0.2^{b}	59.1 ± 0.1^{a}	59.1 ± 0.1^{a}
Linoleic C18:2	53.0 ± 0.0^{a}	52.8 ± 0.2^{b}	53.2 ± 0.0^{a}	53.1 ± 0.0^{a}
α-linolenic C18:3	5.5 ± 0.0^{a}	5.3 ± 0.0^{b}	5.5 ± 0.0^{a}	5.5 ± 0.0^{a}
δ-linolenic C18:3	0.4 ± 0.0^{a}	0.4 ± 0.0^{a}	0.4 ± 0.0^{a}	0.4 ± 0.0^{a}

Means ± standard deviations of the analyses performed in duplicate followed by lowercase letters in the rows do not differ by Tukey test (p > 0.05). SO (soybean oil), TBHQ (soybean oil + TBHQ, Extract (soybean oil + BHT), TWE (soybean oil + tomato waste extract).

Soybean oil consists predominantly of triacylglycerols, often rich in polyunsaturated fatty acids (Chaiyasit *et al*., 2007). Figure 1 illustrates the fatty acids present in the soybean oil added by TWE, with linoleic and oleic acids being in greater amounts. Among the saturated fatty acids, palmitic (C16: 0) was predominant in soybean oil, followed by stearic (C18: 0).

Unsaturated fatty acids, especially polyunsaturated fatty acids, are important because they produce beneficial effects on the body. Among them, the family of n-6 fatty acids, derived from linoleic acid and n-3, derivatives of α-linolenic acid, which help in the prevention and treatment of coronary diseases, hypertension, diabetes, and cancer (Simopoulos, 2004).

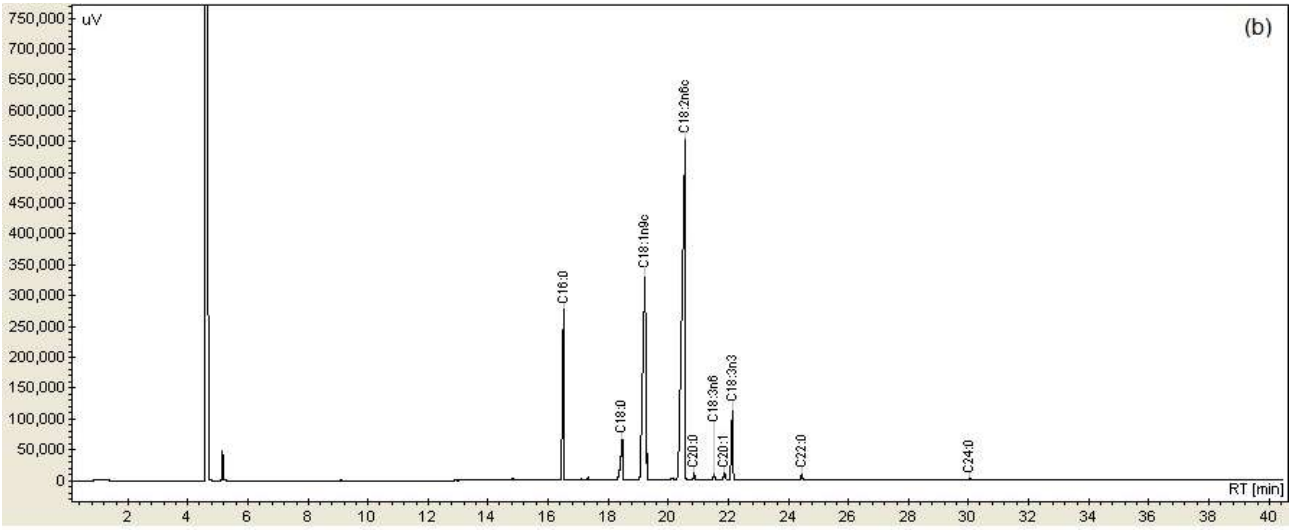

Figure 1. Chromatogram of the fatty acid composition of soybean oil added with TWE (soybean oil + tomato waste extract).

CONCLUSION

Although the extract of the tomato waste presented low levels of lycopene and β-carotene, it showed moderate antioxidant activity and can be used as a natural antioxidant in industrialized oils. ut less effective than the synthetic antioxidant TBHQ. The extract presented an antioxidant effect similar to BHT, therefore it is presented as a natural alternative to be applied in industrialized oils as a natural antioxidant. Among the treatments studied, it was verified that the soybean oil added of TBHQ allowed greater retention of phytosterols and tocopherols, showing greater efficacy in the prevention of lipid oxidation.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest.

CRediT AUTHOR STATEMENT

Irene Rodrigues Freitas: Investigation, Writing - Original Draft and Writing - Review & Editing; **Tayane Lise Siqueira Machado and Débora Maria Moreno Luzia**: Investigation and Writing - Original Draft; **Neuza Jorge**: Conceptualization, Supervision, and Writing- Reviewing and Editing.

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