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EFFECT OF DOMESTIC COOKING ON PHYSICOCHEMICAL PARAMETERS, PHYTOCHEMICALS AND ANTIOXIDANT PROPERTIES OF ALGERIAN TOMATO *(Solanum Lycopersicum L. Var. Marmande)*

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ABSTRACT

Most of the vegetables are consumed after being cooked. Tomatoes are widely consumed either raw or after processing and can provide a significant proportion of the total antioxidants in the diet. This study was performed to investigate the influence of the traditional cooking methods of Algerian people (frying, griddling and baking) on the physicochemical properties (pH, moisture, acidity, Brix, total sugar, ash and non enzymatic browning index), phytochemicals contents (phenolics, flavonoids, anthocyanins, flavonols vitamin C, carotenoids and lycopene) and the antioxidant activity of tomato (*S. lycopersicum*) cultivated in Algeria. Cooking treatment affect positively their physicochemical properties (pH, acidity, Brix, total sugar, ash and non-enzymatic browning index) except the moisture content which decreases significantly. After cooking, the number of phenolics, flavonoids and anthocyanins increase significantly, nevertheless vitamin C, carotenoids and lycopene contents decrease for all cooked samples. Finally, DPPH and ABTS free radicals scavenging activities increased in cooked tomato extracts, while a slight decrease was recorded in ferric reducing power (FRP) due to the reduction of vitamin C contents. Consequently, the antioxidant activity of tomato depends on the cooking procedure and griddling, frying seems to be the best cooking way that enhances its antioxidant activity.

Contribution/Originality: This study documents for the first time to determine the influence of the traditional cooking methods of Algerian people (frying, griddling and baking) on the physicochemical properties, the phytochemicals contents and the antioxidant activity (DPPH, ABTS and FRP) of Algerian tomato (*S. lycopersicum var. Marmande*) used in different food preparation.

1. INTRODUCTION

Tomatoes (*Lycopersicon esculentum* L.) are one of the most widely used and versatile fruit crops. They are consumed fresh and processed into a wide range of manufactured products (D'sousa *et al.*, 2008). Tomato is an important vegetable crop with an excellent source of many nutrients and secondary metabolites that are important for human health; mineral matter, vitamins C and E, β-carotene, lycopene, lutein flavonoids, organic acids, phenolics and chlorophylls (Giovanelli and Paradiso, 2002; Erge and Karadeniz, 2011; Pinela *et al.*, 2012; Erdinc *et al.*, 2018).

Results from the epidemiological studies have shown that tomatoes and tomato products may have a protective effect against various forms of cancer, especially prostate cancer, and cardiovascular diseases (Barber and Barber, 2002; García-Alonso *et al*., 2012; Cheng *et al*., 2017). Typically, this protective action is attributed to antioxidant components like carotenoids (in particular, lycopene and β-carotene), ascorbic acid, flavonoids and tocopherols, with a synergistic interaction among them (Martínez-Valverde *et al*., 2002; Podsędek *et al*., 2003; Raffo *et al*., 2006).

Most of the common vegetables are consumed after being cooked. Tomatoes are widely consumed either raw or after processing and can provide a significant proportion of the total antioxidants in the diet (Martínez-Valverde *et al*., 2002; Ilahy *et al*., 2011). They constitute the predominant source of lycopene and phenols in the Algerian diet because of their year-round availability, high utility in Algerian culinary preparations and their cheap price. However, tomatoes are cooked and processed into products like Catsup, salsa and sauces (King and Zeidler, 2004). Thus, it is important to know the effect of the culinary treatments and the cooking processes (frying, griddling and baking) on their antioxidant activity or free radical capacity.

In general, vegetables are prepared at home by convenience and taste preference rather than retention of nutrient and health-promoting compounds. It is known that cooking process or introduction of a thermal treatment induces an increase, a decrease or induce no significant changes in chemical composition, affecting the bioavailability and content of chemopreventive compounds and the antioxidant activity in vegetables (Martínez-Huélamo *et al*., 2015; Arkoub-Djermoune *et al*., 2016; De Santiago *et al*., 2018).

Cooking methods were shown to affect the contents of nutrient and health-promoting compounds such as carotenoids, vitamin C, polyphenols in vegetables (Sahlin *et al*., 2004; Lin and Chang, 2005; Chuah *et al*., 2008; Adefegha and Oboh, 2011; Murador *et al*., 2014; Arkoub-Djermoune *et al*., 2016; De Santiago *et al*., 2018). However, there is lack of information on the effect of some domestic cooking method like griddling, frying and baking on the physicochemical properties and antioxidant activities of Algerian tomato. Because modern-day consumers seek to avoid aggressive cooking methods which may affect the functionality of foods, there is growing interest in the phytochemical profiles and antioxidant activities of cooked (boiled, microwaved, steamed, grilled, fried, and baked) vegetables.

Therefore, the purpose of this study is to elaborate the effects of three different traditional cooking procedures of Algerian people (frying, griddling and baking) on the physicochemical characteristics and the major antioxidant components (total phenolics, flavonoids, flavonols, anthocyanins, carotenoids, lycopene and ascorbic acid contents) and the antioxidant activity of tomato commercially grown in Algeria.

2. MATERIALS AND METHODS

2.1. Chemicals

Folin-Ciocalteau phenol reagent, potassium ferricyanide ($C_6N_6FeK_3$), ferric chloride ($FeCl_3$-$6H_2O$), trichloroacetic acid were from Biochem, Chemopharma (Montreal, Quebec). Sodium carbonate (Na_2CO_3), acetone, ethanol and methanol were obtained from Prolabo (made in CE). 1,1-Diphenyl-2-picrylhydrazyl (DPPH), and 2,20-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) from Sigma-Aldrich (Sternheim, Germany). Gallic, Quercetrin and Trolox were from Sigma-Aldrich Co (St. Louis, MO, USA).

2.2. Sample Treatment

The fresh tomato (*S. lycopersicum var. Marmande*) was purchased from local market, Bejaia city, Algeria. They are fresh and without infections or wounds, washed by distilled water and prepared for later use. The representative tomato sample (5 kg) was divided into four parts and treated in a different mode. The first batch is kept in its fresh state and others suffered three cooking methods: frying, griddling and baking.

Frying: the second batch of fresh tomato sample was cut into slices put in a pan containing about 100 mL of olive oil and the frying was performed at 160 -165°C during 8 min.

Griddling: the fresh tomatoes were placed on a rack at 160°C for 20 min.

Baking: The fourth batch of fresh tomatoes was cut into the slice and placed in an electric domestic oven previously set at a temperature of 175°C for 25 min.

After cooking, the different samples are stored at -18°C for further extraction and analysis.

2.3. Physico-Chemical Parameters Determination

The tomato samples were studied to determine the following parameters: pH, titratable acidity (Verma and Joshi, 2000) water content, total soluble solids (Brix) (Afnor, 1982). In addition, the amount of total sugar and total ash was assayed according to the method described by Afnor (1982). Finally, the non-enzymatic browning index (NEBI) was performed by a formerly described protocol of Davoodi *et al.* (2007).

2.4. Phenolic Compound Determination

2.4.1. Preparation of the Extracts

Fresh and cooked samples (0.5 g) were extracted with 50 mL of aqueous acetone 70 % (v/v) for 60 min at room temperature. The extracts were then centrifuged at 4000g, for 25 min (Sigma 2-16K, Osterode, Germany), paper filtered and stored at 4°C.

2.4.2. Total Phenolics (TP)

The number of total phenolics in tomato extract fresh or cooked was determined using the Folin-Ciocalteu reagent and gallic acid as standard as described by Velioglu *et al.* (1998). In brief, 200 µL of each extract were added to 1.5 mL of Folin-Ciocalteu reagent (diluted ten times). After 5 min, 1.5 mL of sodium carbonate (60 g/L) are added. The mixture kept in the dark for 90 min and the absorbance was measured at 760 nm using a Shimadzu UV–Vis spectrophotometer (Kyoto, Japan). The results are expressed as milligram Gallic Acid Equivalent per one hundred gram of the fresh weight (mg GAE/100 g FW).

2.4.3. Total Flavonoids (TFA)

The total flavonoids contents of the extract were evaluated following colorimetric assay of Djeridane *et al.* (2006). Briefly, 1.5 mL of the extract was added to 1.5 mL of 2 % aluminium chloride (w/v). After 10 min, the absorbance was measured at 430 nm. The amount of total flavonoids in the extract is determined by using quercetin as a standard and reported as milligram Quercetine Equivalent per one hundred gram of the fresh weight (mg QE/100 g FW).

2.5. Total Anthocyanins (TA) and Total Flavonols (TFO)

Anthocyanins were extracted according to the procedure described by Ganjewala *et al.* (2008). In this procedure, 1 g of each sample was extracted with 1.0 mL methanol 0.1 N HCl for 30 min and the extract decanted. Then, 20 µL of the extract was added to 980 µL methanol 0.1 N HCl and the absorption spectrum recorded in a spectrophotometer. The total anthocyanins contents were reported from the absorbance at 530 nm using a molar extinction coefficient (ε) of 38 000 L x mol^{-1} x cm^{-1} and that of the flavonol glycosides at 360 nm (ε = 20000 L x mol^{-1}x cm^{-1}, recorded from a pure sample of quercetin 3-glucoside). The contents of TA and TFO expressed as milligram Quercetin 3-Glucoside Equivalent per one hundred gram of the fresh weight (mg Q3GE/100 g FW).

2.6. Total Carotenoids (TC) and Lycopene Contents (LC)

Carotenoids are pigment insoluble in water and soluble in apolar solvents such as hexane. Total carotenoids were extracted from the samples using the method of Sass-Kiss *et al.* (2005). In brief, 20 mL mixture hexane-acetone-ethanol (2:1:1, v: v: v) were added to 2 g of homogenized fresh or cooked samples. After 30 min agitation,

the supernatant was collected and the residue was added with 10 mL hexane for a second extraction. The absorbance of the combined hexane layers was measured at 420 nm using Shimadzu UV–Vis spectrophotometer (Kyoto, Japan). The total carotenoids contents in the samples were determined from the standard curve using β-carotene and the results were expressed as milligram β-Carotene Equivalent per one hundred gram of the fresh weight (mg βCE/100 g FW).

The lycopene contents were determined after measuring the absorbance of the supernatant at 472 nm. The results were reported as milligram Lycopene Equivalent per one hundred gram of the fresh weight (mg LE/100 g FW) from the standard curve of lycopene.

2.7. Ascorbic Acid (AA)

Ascorbic acid was determined as described by Mau *et al.* (2005) with slight modifications. One gram of each sample was extracted with 10 mL of oxalic acid 1 % (w/v) for 45 min at room temperature and filtered. The filtrate (1 mL) was mixed with 9 mL of 2,6-dichloroindophenol and the absorbance was measured within 15 sec at 515 nm against a blank. The vitamin C contents were calculated by the calibration curve used L-ascorbic acid as standard and the result expressed as milligram Ascorbic Acid Equivalent per one hundred gram of the fresh weight (mg AAE/100 g FW).

2.8. Antioxidant Activity

Several methods have been developed to assay free radical scavenging capacity and total antioxidant activity of the extracts. In our study, we used three methods: scavenging of the radical DPPH, scavenging of the radical ABTS activities and ferric reducing power.

2.8.1. Free Radical Scavenging Activity of DPPH (FRSA)

The ability of the extracts to scavenge DPPH free radicals was determined by the method of Milardović *et al.* (2006). 100 µL of samples extract at different concentration were mixed with 3 mL of DPPH in methanol (6.10^{-5}M). After 30 min of incubation in the dark and ambient temperature, the absorbance was measured at 515 nm. The percentage scavenging was calculated according to the following equation:

$$FRSA\ (\%) = [(A_{contr} - A_{extr})/A_{contr}].100$$

Where A_{contr} is the absorbance of the control (without extract) after 30 min and A_{extr} is the absorbance of extract.

The inhibition percentage was expressed as milligram Trolox Equivalent per gram of the fresh weight (mg TE/g FW) and the IC_{50} was calculated as the concentration of extracts causing a 50 % inhibition of DPPH radical.

2.8.2. Free Radical Scavenging Activity of ABTS (FRSA)

The Antioxidant capacity of the extract was also determined by scavenging of the radical 2,20-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), as described by Re *et al.* (1999) with slight modifications. The stock solution was prepared by stirring ABTS (7 mM) and potassium persulfate (2.45 M) in water overnight. Before use, this solution was diluted in ethanol to obtain an absorbance of 0.7 ± 0.020 at 734 nm. In the assay, 20 µL of different concentration of extract, standard (Trolox) or blank (ethanol), and 2 mL of ABTS solution was mixed. The absorbance at 734 nm was determined after 4 min. For each extract, a blank with 1 mL of ethanol, instead of ABTS reagent, was included to correct for any sample absorbance at 734 nm. The percentage of scavenging was calculated according to the following equation:

$$FRSA\ (\%) = [(A_{contr} - A_{extr})/A_{contr}].100$$

Where A_{contr} is the absorbance of the control (without extract) after 4 min and A_{extr} is the absorbance of extract.

The inhibition percentage was expressed as milligram Trolox Equivalent per gram of the fresh sample (mg TE/g FW) and the IC_{50} was calculated as the concentration of extracts causing a 50 % inhibition of ABTS radical.

2.8.3. Ferric Reducing Power (FRP)

The reducing power of the extracts was evaluated according to the protocol of Oyaizu (1986). One milliliter of different concentrations of the samples were mixed with phosphate buffer (1 mL, 0.2 M, pH = 6.6) and potassium ferricyanide [$K_3Fe(CN)_6$] (1 mL 1 g/100 mL). The mixture was incubated at 50°C for 20 min. Trichloroacetic acid (TCA) (1 mL, 10 g/ 100 mL) was added to the solution and then centrifuged for 10 min at 3000g. The supernatant was gathered, mixed with distilled water (1.5 mL) and $FeCl_3$ (150 µL, 0.1 g/100 mL), finally the absorbance was measured at 700 nm, increased absorbance of the reaction mixture indicate an increase in reducing power. Results are expressed as milligram Trolox Equivalent per gram of fresh weight (mg TE/g FW). The $RC_{0.5}$ was calculated as the concentration of extracts reducing 50 % of ferric ions.

2.9. Statistical Analysis

All analyses were carried out in triplicate and the results were expressed as means ± standard deviation. The analysis of variance (ANOVA) was performed using STATISTICA 5.5 to compare significant differences between the samples. Differences at $p<0.05$ were considered statistically significant.

3. RESULTS AND DISCUSSION

3.1. Physico-Chemical Properties of Fresh and Cooked tomatoes

Table 1 shows the pH, water content, acidity, total sugar, TSS (Brix), ash and NEBI of raw and cooked tomatoes. The pH values of the different samples are significantly different ($p<0.05$), they are between 4.15 ± 0.01 and 4.44 ± 0.02.

Table-1. Physico-chemical properties of fresh and cooked tomatoes.

State	pH	Moisture (%)	Acidity (%)	Total sugar (%)	TSS (%)	Ash (%)	NEBI
Fresh	4.15 ± 0.01^{a}	94.60 ± 0.29^{c}	2.54 ± 0.12^{b}	0.43 ± 0.13^{a}	4.23 ± 0.55^{a}	0.15 ± 0.01^{a}	0.28 ± 0.55^{a}
Fried	4.31 ± 0.01^{c}	84.70 ± 1.02^{b}	2.98 ± 0.12^{c}	0.80 ± 0.27^{c}	8.33 ± 0.23^{c}	0.55 ± 0.03^{b}	0.62 ± 0.23^{d}
Grilled	4.44 ± 0.02^{d}	83.03 ± 0.85^{b}	1.99 ± 0.19^{a}	$0.57 \pm 0.03^{a,b}$	6.83 ± 0.23^{b}	0.50 ± 0.01^{b}	0.32 ± 0.23^{b}
Baked	4.25 ± 0.02^{b}	1.53 ± 1.25^{a}	$2.24 \pm 0.24^{a,b}$	$0.52 \pm 0.04^{a,b}$	7.03 ± 0.05^{b}	0.55 ± 0.04^{b}	0.44 ± 0.05^{c}

Each value in the table is the mean ± standard deviation (n = 3).
Values in the same column sharing different letters are significantly different ($p<0.05$). Results are ranked in ascending order; d> c> b > a.

The pH of cooked tomatoes increases slightly after cooking compared to the fresh sample (4.15 ± 0.01). It rises with the rate of 6.53 %, 3.71 % and 2.35 % in grilled, fried and baked tomatoes, respectively. A similar result were found in our study on the effect of the three cooking methods tested on eggplant (Arkoub-Djermoune *et al.*, 2016) which may be attributed to the extraction organic acids after softening of the cell walls in cooked samples and/or to their degradation during cooking, which induced a proton release. Furthermore, the increase of pH in cooked tomatoes could be ascribed to the reduction of available carboxylic groups of proteins (Ergezer and Gokce, 2011).

The moisture test allows to know the water content of the different samples studied. The results show significant differences ($p<0.05$) between the water content of the fresh samples and the cooked one Table 1. The water content of the fresh tomato is 94.60 ± 0.29 % and it decreases with a percentage of 10.46 % to 98.38 %. These results were consistent with those reported by Scalzo *et al.* (2016); Arkoub-Djermoune *et al.* (2016) and De Santiago *et al.* (2018) this loss is the result of heat treatment (Sahlin *et al.*, 2004). According to Utra *et al.* (2016) cooking usually induces water removal, thus causing a reduction in moisture and therefore an increase in nutrient content such as ash. Moreover, Kalogeropoulos *et al.* (2010) have reported that the main change in the composition of vegetables during frying is the loss of water due to evaporation and absorption of the oil.

The acidity of tomato samples varies significantly ($p<0.05$) and ranged between 1.99 ± 0.12 and 2.98 ± 0.11 % Table 1. The fried tomato presented the highest content (2.98 ± 0.12), followed by baked tomato (2.24 ± 0.24 %) and grilled tomato (1.99 ± 0.19 %). Frying caused an increase with a rate of 14.76 %. Nevertheless, a slight decrease observed in grilled and baked tomatoes with proportions of 21.65 % and 11.81 %, respectively. These results are consistent with those reported in our study on the eggplant and we found that frying increase the acidity with a rate of 33.33% but baking decrease it with a percentage of 25.80% (Arkoub-Djermoune *et al*., 2016) which may be due to the degradation of certain organic acids during cooking, mainly citric acid. Indeed, they can also react with sugars during cooking by the condensation Maillard reaction, thus leading to the formation of brown polymers (Armesto *et al*., 2016) confirming the increase in non-browning enzymatic in the fried sample. However, the increase in acidic content recorded in fried tomato can be due to greater extraction of organic acids after softening of the cell wall by heat treatment and/or attributed to the reduction the water content which leads to an increase in the pH value. These results suggest that cooking can have both a positive and a negative effect depending on the cooking mode of the samples.

The total sugars of raw and cooked tomatoes are extended between 0.43 ± 0.13 % and 0.80 ± 0.27 % Table 1. The lowest value is recorded in the fresh tomato with a content of 0.43 ± 0.13 %. All cooking treatment caused a significant increase in total sugars content with levels of 17.30 %, 24.56 % and 46.25 % in baked, grilled and fried tomato, respectively. In fact, Maceiras *et al.* (2007); Armesto *et al.* (2016) and De Santiago *et al.* (2018) reported that the sugar content in some fruits and vegetables increase during cooking, which confirms the values obtained in our study. According to De Santiago *et al.* (2018) heat treatment induces depolymerisation and the rupture of some glycosidic linkage in dietary fiber polysaccharides that favor the observed increase in carbohydrates.

The total soluble solids (TSS) is primarily represented by sugars, with acids and minerals contributing. The results obtained for TSS (Brix) vary significantly ($p<0.05$), they are ranged from 4.23 ± 0.55 % to 8.33 ± 0.23 % Table 1. The Brix of fresh tomato is 4.23 ± 0.55 %, it increases after cooking with different range of 49.21 % (fried tomato), 39.82 % (baked tomato) and 30.06 % (grilled tomato). These results were confirmed by dos Dos *et al.* (2015) and Arkoub-Djermoune *et al.* (2016) which is explained by the higher water loss and sugar concentration.

The ash content is the total quantity of minerals present in the sample. Table 1 shown that cooking increase significantly ($p<0.05$) the content of mineral matter in cooked tomato. Griddling, baking and frying of tomato increase the mineral content with a proportion of 70 % to 72 %. Mineral components show great changes during cooking operations, because of their solubility in water. Cooking might improve mineral bioavailability by increasing solubility due to cell wall disruption, protein denaturation and release of organic acids, which is found by Lopes *et al.* (2015) in cooked broccoli, kale, cabbage and Arkoub-Djermoune *et al.* (2016) in eggplant. According to Lopes *et al.* (2015) the increase of ash content found in cooked samples either can be due to the water loss by evaporation inducing a concentration of minerals.

The development of some non-enzymatic browning reactions, such as Maillard reaction, has been recently associated with the formation of compounds with strong antioxidant capacity (Manzocco *et al*., 2000). The initial browning of tomato is probably due to enzymatic reactions and essentially to non-enzymatic browning (Maillard Reaction) that occurred during cooking. Indeed, the enzymatic browning is disfavored by lowering the pH and thermal treatment. However, the non-enzymatic browning is favored by heating and it can still occur at pH 4.0 (Benmeziane *et al*., 2018). The results of the NEBI are shown in Table 1. The degree of NEBI for different batches of tomato analyzed present a significant difference ($p<0.05$), they vary from 0.28 ± 0.55 to 0.62 ± 0.23. After cooking, the NEBI increase significantly with a proportion of 54.83 % in fried tomato, followed by the baked tomato with a range of 36.36 % and finally the grilled tomato with a percentage of 12.50 %. A similar result have been reported in our study (Arkoub-Djermoune *et al*., 2016) that the index of NEB of eggplant increases after cooking with a range of 48.89%, 66.18% and 76.76% in grilled, fried and baked sample, respectively. Indeed, Sharma and Gujral (2011) reported that the non-enzymatic browning index of barley increase after griddling with a range of

315 % to 774 %. According to Manzocco *et al.* (2000) this increase in NEBI during processing due to a formation of antioxidant Maillard reaction products which promote changes in antioxidant properties, and they are positively correlated with the development of browning. A positive correlation achieved between colour and antioxidant properties in processed foods.

To our knowledge no results have been reported in the literature on the effect of the three cooking methods tested on the physicochemical characteristic: pH, acidity, Brix and NEBI of tomato.

3.2. Antioxidant Contents

3.2.1. Total Phenolic Content (TP)

A comparison of the TP data of the fresh and cooked tomatoes is given in Table 2. There are significant differences ($p<0.05$) between the fresh and cooked samples.

Table-2. Total Phenolics (TP), Total Flavonoids (TFA), Total Flavonols (TFO), Total Anthocyanins (TA) of fresh and cooked tomatoes.

Tomato	TP (mg GAE/100g)	TFA (mg EQ/100g)	TFO (mg Q3GE/100 g)	TA (mg Q3GE/100 g)
Fresh	72.42 ± 3.87^{a}	7.09 ± 0.69^{a}	4.60 ± 0.29^{c}	1.25 ± 0.067^{a}
Fried	585.56 ± 24.09^{d}	20.77 ± 3.07^{c}	5.03 ± 0.14^{c}	1.61 ± 0.219^{a,b}
Grilled	314.50 ± 16.29^{c}	14.42 ± 1.38^{b}	3.34 ± 0.46^{b}	1.73 ± 0.269^{b}
Baked	230.71 ± 22.71^{b}	10.51 ± 3.07^{a,b}	1.38 ± 0.07^{a}	1.97 ± 0.112^{b}

Each value in the table is the mean ± standard deviation (n = 3).
Values in the same column sharing different letters are significantly different ($p<0.05$). Results are ranked in ascending order; d> c> b > a.

The TP contents ranged from (72.42 ± 3.87 to 585.56 ± 24.09 mg GAE/100 g of fresh weight) and the lowest value is noted in fresh tomato with a tenor of 72.42 mg ± 3.87 GAE/100 g FW. The TP content increase significantly ($p<0.05$) in the cooked samples with a proportion ranged from 68.60 % to 87.63 %. The order of TP content was as follow: Fried > Gried > Baked> Fresh Table 2. These results are in agreement with those reported by Arkoub-Djermoune *et al.* (2016); Girgin and El (2015); McDougall *et al.* (2010); Sahlin *et al.* (2004) and Turkmen *et al.* (2005).To our knowledge, there is no published data regarding the effect of griddling on the TP of tomato. Bernhardt and Schlich (2006) and McDougall *et al.* (2010) suggests that cooking can increase the extractability and therefore the bioavailability of phenolic compounds. This would be the consequence of softening and breaking walls cell, thereby increasing the concentration of these compound. Sahlin *et al.* (2004) have noted that boiling and baking caused a slight increase in total phenolic. However, Dewanto *et al.* (2002) obtained in their study that heating at 80°C has no significant effect on the total phenol content of tomato. This divergence recorded in cooking effect on the phenolic content may be explained by the differences in the cooking method, time and temperature.

3.2.2. Total Flavonoids Content (TFA)

The mean values of TFA contents of fresh and cooked tomatoes specimen are presented in Table 2. There are large variations and significant differences ($p<0.05$) in TFA contents between fresh and cooked tomatoes. The TFA contents ranged from 7.09 ± 0.69 to 20.77 ± 3.07 mg QE/100 g FW. The levels of TFA rise significantly in the cooked sample compared to the fresh one with a percentage of 32.54 % to 65.86 %. The samples can be ranked from the highest to the lowest TFA content as fried > grilled > baked > fresh tomato with a tenor of 7.09 ± 0.69 mg QE/100 g FW. According to Olivera *et al.* (2008) the increase in the TFA contents is related to the loss of tissue integrity, the cells and organelles membranes after heat treatment. whereas, Dewanto *et al.* (2002) have reported that heat treatment has no significant changes in total flavonoids of tomato. This probably due to the differences on the temperature and the time of cooking.

3.2.3. Total Flavonols Content (TFO)

To our knowledge, there is no published data regarding the effect of griddling on the total flavonol contents in tomato fruits. Table 2 shows that flavonol content was significantly different ($p<0.05$) among the tested samples. The TFO contents varied from 1.38 ± 0.07 to 5.03 ± 0.14 mg Q3GE/100 g FW. The fresh tomato has a concentration of 4.60 ± 0.29 mg Q3GE/100 g FW. Frying caused an increase in the flavonol content with a rate of 8.54 % which is in accordance with those reported by Arkoub-Djermoune *et al.* (2016) and Turkmen *et al.* (2005). Whereas, their levels decrease after baking, griddling with proportions of 15.21% and 27.39 %, respectively.

3.2.4. Total Anthocyanins Content (TA)

The TA contents of raw and cooked tomatoes are shown in Table 2. It increases in cooked tomatoes with a percentage of 22.36 % to 36.54 %. The order of TA contents was as follow baked > grilled > fried > fresh with a level of 1.25 ± 0.067 mg Q3GE/100 g FW. Regarding the effect of cooking treatment, the result reported by Oren-Shamir (2009) support and confirm the results obtained in this study. According to McDougall *et al.* (2010) The high level of anthocyanins in the cooked samples is due to the ease with which they are extracted, following a sharp cell wall weakening of the skin by heat treatment.

3.2.5. Ascorbic Acid Content (AA)

The AA contents showed great variations between the fresh and cooked tomatoes, and the range was from 12.94 ± 0.23 to 21.15 ± 0.21 mg AAE/100 g FW Table 3. The high vitamin C content was obtained in a fresh sample with a tenor of 21.15 ± 0.21 mg AAE/100 g FW. Depending on the vitamin C contents, the samples can be indexed as follow fresh > baked > fried > grilled. The data shown in the Table 3 indicate that domestic cooking cause a significant decrease at $p<0.05$ of AA contents in cooked tomatoes samples with proportions ranged between 25.67 % and 38.81 %, agreeing with result found by Dewanto *et al.* (2002); Joshua and Suleiman (2012) and Arkoub-Djermoune *et al.* (2016). Several other studies have shown that cooking decrease the vitamin C contents in vegetables, Arkoub-Djermoune *et al.* (2016) in eggplant, Chuah *et al.* (2008) in pepper and Nicoli *et al.* (1997) in tomato varieties. Moreover, Sahlin *et al.* (2004) have shown that boiling and baking had a relatively small effect on the ascorbic while frying significantly reduced the ascorbic acid contents of two cultivars. The reduction of the vitamin C content in cooked tomato is the result of thermal treatment which is known to accelerate oxidation of ascorbic acid to dehydroascorbic acid, followed by the hydrolysis to 2,3-diketogulonic acid and eventually polymerization to other nutritionally inactive components (Arkoub-Djermoune *et al.*, 2016). The loss of vitamin C in the cooked samples depend on the temperature, the time of heat treatment and the cooking method.

3.2.6. Total Carotenoid (TC) and Lycopene Contents (LC)

Tomato contains a significant quantity of β-carotene that has vitamin A activity. The recorded data on the cooking effect on carotenoid and lycopene contents are shown in Table 3. There were significant differences ($p<0.05$) between the samples. The TC contents of different batches of tomatoes are ranged between 2.71 ± 0.04 and 5.54 ± 0.08 mg ßCE/100 g FW. The highest rate is obtained in fresh tomato with a value of 5.54 ± 0.08 mg ßCE/100 g FW. The order of TC contents was as follow: fresh > fried > baked > grilled.

Table-3. Ascorbic Acid (AA), Total Carotenoid (TC) and Lycopene Contents (LC) of fresh and cooked tomatoes.

Tomato	AA (mg AAE/100g)	TC (mg βCE/100g)	LC (µg LE/100g)
Fresh	21.15 ± 0.21^{c}	5.54 ± 0.08^{d}	2500.63 ± 77.32^{d}
Fried	13.72 ± 0.61^{a}	4.41 ± 0.08^{c}	1757.63 ± 29.70^{b}
Grilled	12.94 ± 0.23^{a}	2.71 ± 0.04^{a}	1232.50 ± 27.16^{a}
Baked	15.04 ± 0.02^{b}	3.54 ± 0.20^{b}	1978.50 ± 11.18^{c}

Each value in the table is the mean ± standard deviation (n = 3).
Values in the same column sharing different letters are significantly different ($p<0.05$). Results are ranked in ascending order; d> c> b > a.

The levels of TC decrease respectively after frying, baking, griddling with the percentage of 20.39 %, 36.10 % and 51.08 %. This result is in accordance with those reported by Murador *et al.* (2014) and Arkoub-Djermoune *et al.* (2016). Moreover, Rodriguez-Amaya and Kimura (2004) reported that heat treatment causes *Cis/Trans* isomerization of carotenoids, altering their biological activities which justifies the reduction of total carotenoid content in cooked sample.

Lycopene is one of the most important carotenoid present in red tomato. Their amount in fresh tomato was 2500.63 ± 77.32 µg LE/100 g FW. Similarly to the TC contents, the lycopene contents (LC) of tomatoes analyzed show a significant difference at $p<0.05$ Table 3. The LC decrease with a range of 20.87 %, 29.71 % and 50.71 % in baked, fried, grilled tomatoes, respectively. This result is confirmed by Sahlin *et al.* (2004) that frying reduces the lycopene contents of two tomato cultivars. Furthermore, Dewanto *et al.* (2002); Mayeaux *et al.* (2006); Murador *et al.* (2014); Arkoub-Djermoune *et al.* (2016).

3.3. Antioxidant Activity

Fruits contain different bioactive compounds. Therefore, measuring the antioxidant capacity of each compound individually becomes very difficult. Several methods have been developed to estimate the antioxidant potential of different plant materials. Usually, these methods measure the ability of antioxidants to scavenge specific radicals, inhibit lipid peroxidation or chelate metal ions. In the present work, three methods (DPPH, ABTS and FRP) were used to evaluate the antioxidant capacity of the fresh and cooked tomatoes fruit extracts.

3.3.1. Free Radical Scavenging Activity of DPPH (FRSA)

The inhibition percentage of DPPH radical expressed as milligram Trolox Equivalent per gram of the sample shown in Figure 1 indicate that the antiradical activity increases gradually as the extract concentration rises in fresh and cooked samples. The antiradical power result is expressed in terms of IC_{50} Table 4 and represent the concentration of the sample, which inhibits 50 % of the DPPH radical, a low IC_{50} corresponds to a high antiradical capacity. The results showed that the extract of the fresh tomato inhibit 50 % of DPPH radical with a concentration of 4.07 ± 1.38 mg/mL thus permit to conclude that uncooked tomato posses the best antiradical activity than the cooked one.

Table-4. The IC_{50} and the $CR_{0.5}$ of fresh and cooked tomatoes.

Sample	Inhibition Concentration IC_{50} (mg/mL)		Reducing Capacity $RC_{0.5}$ (mg/mL)
	FRSA (DPPH)	FRSA (ABTS)	FRP
Fresh	4.07 ± 1.38^{a}	6.21 ± 0.01^{a}	4.82 ± 0.03^{a}
Fried	4.89 ± 0.02^{b}	4.68 ± 0.01^{b}	5.10 ± 0.00^{c}
Grilled	4.84 ± 0.01^{b}	4.66 ± 0.01^{b}	4.92 ± 0.03^{b}
Baked	4.84 ± 0.01^{b}	4.75 ± 0.00^{c}	5.00 ± 0.00^{c}

Each value in the table is the mean ± standard deviation (n = 3).
Values in the same column sharing different letters are significantly different ($p<0.05$). Results are ranked in ascending order; c> b > a.

The results of the DPPH antiradical efficiency were consigned in Figure 1 and revealed clearly that the thermal treatment tested had a strong effect on the free radical scavenging ability. Significant ($p<0.05$) differences in the antiradical power were noticed between the samples. The inhibition proportion of DPPH radical by the fresh tomato extract was 28.70 ± 0.11 mg TE/g FW. Indeed, extracts from the cooked sample are more active than from the raw sample. The proportion of free radical DPPH inhibition varies from 29.79 ± 0.05 mg TE/g FW to 30.94 ± 0.05 mg TE/g FW and the grilled tomato presented the best antioxidant activity Figure 1. These results are consistent with those reported by Turkmen *et al.* (2005) and McDougall *et al.* (2010). Moreover, Lin and Chang (2005) noted that a pre-cooking and/or baking has no significant effect on the antioxidant properties of broccoli.

Furthermore, Faller and Fialho (2009) reported that cooking (boiling in water, microwave and steaming) reduce the antiradical activity of some vegetables (potato, carrot, onion, broccoli, white cabbage). Also, similar result observed by Oboh *et al.* (2005) in eggplant leaves and Amin *et al.* (2006) in spinach.

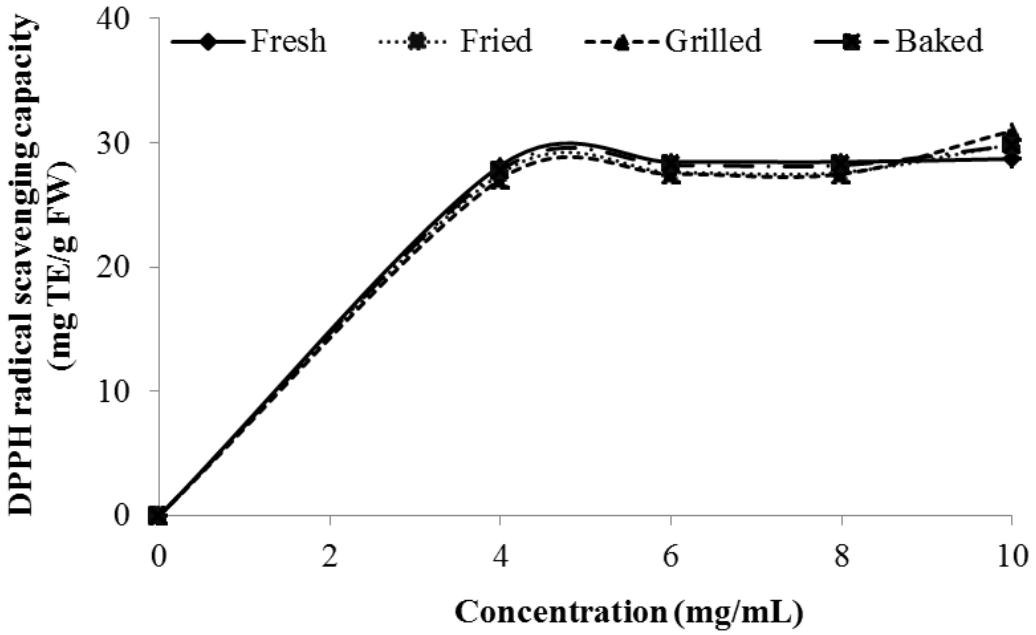

Figure-1. DPPH radical scavenging capacity of fresh and cooked tomato extracts at different concentration.

3.3.2. Free Radical Scavenging Activity of ABTS (FRSA)

The results of the inhibition of the radical $ABTS^{\bullet+}$ are expressed in terms of IC50 Table 4 a low IC50 indicate a strong inhibition. The results obtained show a variation of the inhibitory activity of different tomato samples in Figure 2. The grilled and the fried tomato trap respectively 37.89 ± 0.14 mg TE/g FW and 37.89 ± 0.19 mg TE/g FW of $ABTS^{\bullet+}$ radical, followed by the baked tomato (36.97 ± 0.09 mg TE/g FW) and then the fresh sample with a proportion of 28.17 ± 0.24 mg TE/g FW. This can be due to their high content on vitamin C and lycopene with good antioxidant power.

This result is confirmed by the calculation of the IC_{50} of the different specimen Table 4. The recorded data indicate that only a concentration of 4.66 ± 0.01 mg/mL for the grilled tomato and 4.68 ± 0.01 mg/mL for the fried tomato requisite to inhibit 50 % of the radical $ABTS^{\bullet+}$.

This increase in the antiradical activity can be due to the rise of phenol contents and the NEBI in cooked samples. These results are in agreement with those reported by Dewanto *et al.* (2002); Huang *et al.* (2006) and Arkoub-Djermoune *et al.* (2016). Moreover, Sahlin *et al.* (2004) have shown that boiling and baking had a relatively small effect on the antioxidant activity of the two cultivars. However, Jiménez-Monreal *et al.* (2009) noted that griddling, frying, baking, boiling and pressure cooking reduce the antioxidant ability of some vegetables.

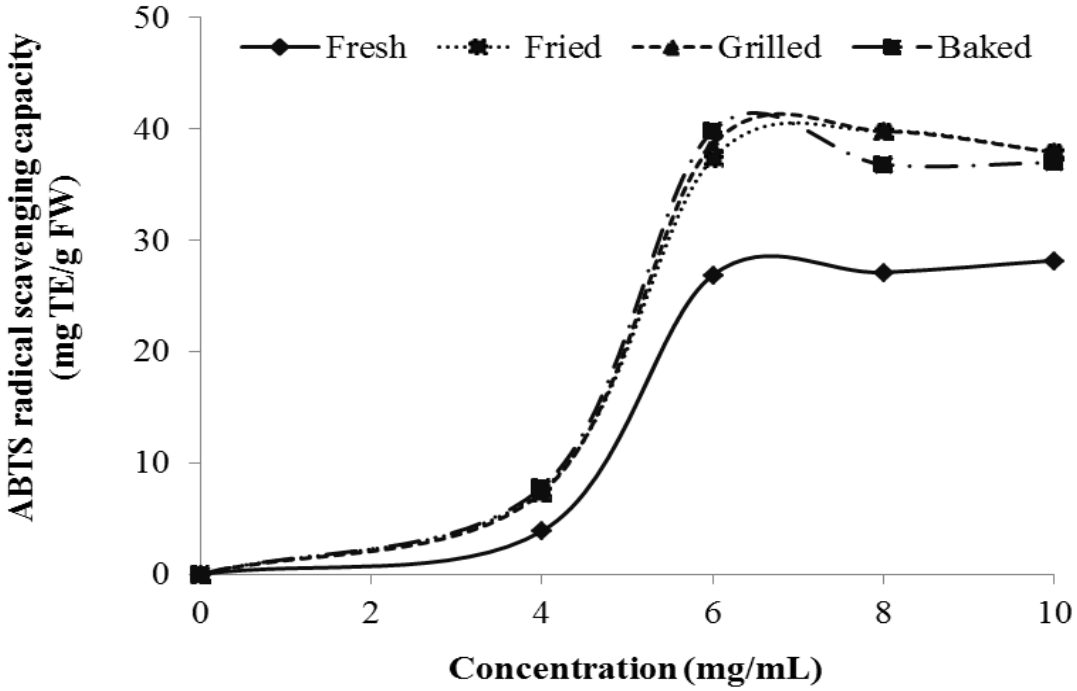

Figure-2. ABTS radical scavenging capacity of fresh and cooked tomato extracts at different concentration.

3.3.3. Ferric Reducing Power (FRP)

The reducing power is expressed by the reducing capacity "$RC_{0.5}$", which corresponds to the concentration of products giving an absorbance of 0.5, plus the $RC_{0.5}$ is lower than more the absorbance increases and the reducing power is strong. The values of $RC_{0.5}$ (expressed in mg/mL) of different extracts are summarized in Table 4. Based on these results, fresh tomato gives the lowest $RC_{0.5}$ (4.82 ± 0.03 mg/mL), so the most important activity and fried tomato gave the highest $RC_{0.5}$ with a value (5.10 mg/mL) corresponding to lower activity. This result was in line with those reported by Oboh *et al.* (2005) that reducing power decline in some green vegetables, due to the loss of vitamin C (20 to 60 %).

The results of reducing power expressed as milligram Trolox Equivalent per gram of extract at different concentration is shown in the Figure 3. As it can be noted, the reducing power increases as the concentration of the extract rises for all samples. The reducing power of the fried, the baked and the grilled samples need a less concentrations to reduce the ferric iron comparatively to the fresh sample (46.42 ± 0.13 mg TE/g FW), which are 44.23 ± 0.08 mg TE/g FW, 44.69 ± 0.05 mg TE/g FW and 45.25 ± 0.15 mg TE/g FW, respectively. This slight reduction on reducing power between the fresh and cooked tomatoes probably due to the loss of ascorbic acid in cooked sample.

The divergence in the data recorded between the fresh and cooked sample extract probably due to the concentration of TP in the cooked specimen extract and/or to the capacity of these substances to give the electrons. Nevertheless, Huang *et al.* (2006) reported that the reducing power of the sweet potato increases after cooking, due to better extraction of antioxidant components. To our knowledge, there is no published data regarding the effect of the three cooking way tested on the reducing power of tomato.

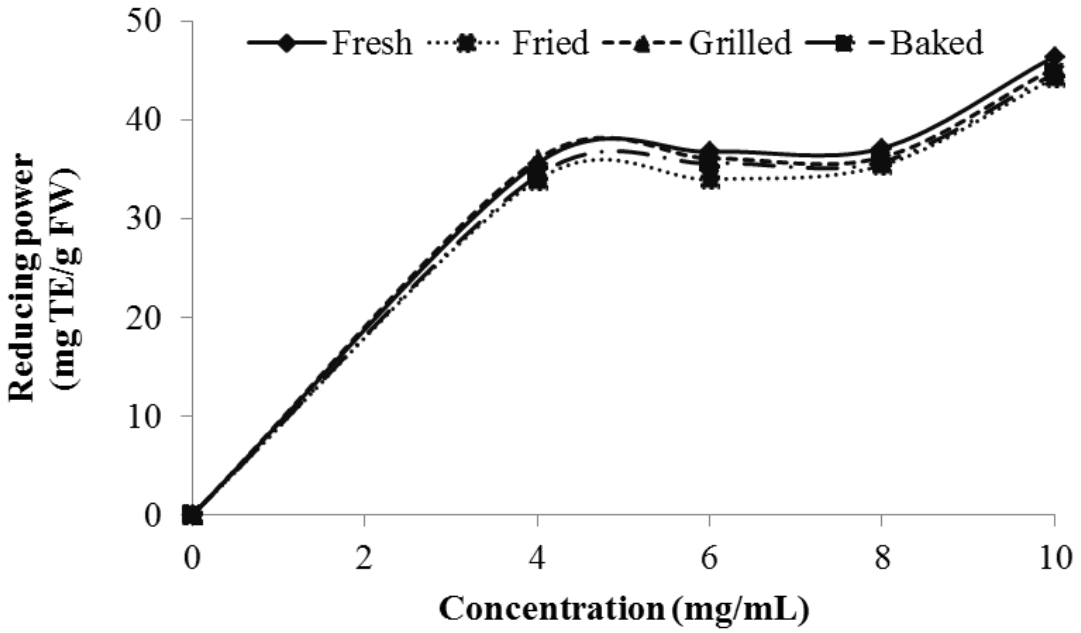

Figure-3. Ferric reducing power of fresh and cooked tomato extracts at different concentration.

3.4. Pearson Correlation Analysis

The extracts of *Solanum lycopersicum* present a significant correlation at $p<0.05$ Table 5 between anthocyanins, flavonoids and the antiradical activity of ABTS radical (r = 0.677, r = 0.672) and highly significant ($p<0.01$) between polyphenols and antiradical activity of ABTS (r = 0.746).

Table-5. Correlation matrix between antioxidants and the antioxidant activity of tomato extract.

Solanum lycopersicum	**TP**	**TFA**	**TFO**	**TA**	**AA**	**TC**	**LC**	**FRSA-DPPH**	**FRSA-ABTS**	**FRP**
TP	1									
TFA	0.891***	1								
TFO	0.308	0.296	1							
TA	0.258	0.157	0.644	1						
AA	-0.743	-0.690	0.260	-0.612	1					
TC	-0.276	-0.273	0.574	-0.668	0.836***	1				
LC	-0.564	-0.563	0.151	-0.438	0.905***	0.881***	1			
FRSA-DPPH	0.488	0.477	0.272	0.539	-0.899	-0.932	-0.988	1		
FRSA-ABTS	0.746**	0.677*	0.330	0.672*	-0.984	-0.812	-0.836	0.841***	1	
FRP	-0.845	-0.708	0.182	-0.563	0.816***	0.476	0.519	-0.506	-0.882	1

TP: total phenolics, TFA: total flavonoids, TFO: total flavonols, TA: total anthocyanins, AA: ascorbic acid, TC: total carotenoid, LC: lycopene contents, FRSA-DPPH: free radical scavenging activity against DPPH free radical, FRSA-ABTS: free radical scavenging activity against ABTS free radical and FRP: ferric reducing power. *** Very highly significant at p<0.001, ** Highly significant at p<0.01, * Significant at $p<0.05$.

In the same way, the contents of ascorbic acid were very highly correlated at $p<0.001$ with reducing power (FRP) (r = 0.816). This suggests that these antioxidants are the main compounds responsible for the antioxidant activity of the tomato. These results are similar to those reported by several authors (Velioglu *et al.*, 1998; Padmashree *et al.*, 2007). Indeed, the phenolic compounds are recognized as potentially antioxidant substances with the ability to trap radical species. These results are confirmed by several authors (Zhang and Hamauzu, 2004; Baljeet *et al.*, 2016). The antioxidant activity depends not only on the concentration of polyphenols but also their chemical structure (the number and the position of the hydroxyl groups) (Sroka and Cisowski, 2003). In addition, other very high significant correlations have been observed between certain antioxidants Table 5 which shows a synergistic effect between these antioxidants involved in the antioxidant activity of tomato. However, no significant correlation was found between polyphenols, ferric reducing power and antiradical activity of DPPH radical.

In conclusion, the current study clearly shows that nutrient and health-promoting compounds in tomato are significantly affected by domestic cooking. The cooking methods leads to an increase of some physicochemical properties (pH, acidity, total sugar, Brix, ash and NEBI) but a decrease in moisture contents was observed in the different cooked samples and with different proportion. The levels of antioxidants in raw tomato are significantly different ($p<0.05$). They are classed as follows: TP > AA > TFA > TC > TFO > LC > TA.

Heat treatment particularly frying, griddling and baking caused a great loss of vitamin C, total carotenoid (TC) and lycopene contents (LC) with different ranges depending on the cooking treatment. All cooking treatment caused a significant increase in the contents of phenolic substances (TP, TFA, TFO and TA) with the exception of baked tomato, where oven cooking induced decrease of flavonols contents.

The antiradical activities increase after cooking treatment with different proportion depending on cooking way. While a slight decrease was detected in the reducing power after cooking probably due to the loss of vitamin C in cooked samples. Therefore, tomato (*Solanum lycopersicum*) raw or cooked may be considered a source of important phytochemicals with an important antioxidant property. Regarding the antioxidant activities, the tomato samples studied are ranged as follows: grilled ≈ fried > baked > fresh allowed concluding that the antioxidant properties of grilled and fried tomatoes are better than the fresh tomato samples. The antioxidant activity of cooked tomato fruit depends on the way, the time and/or the temperature of the cooking process.

In summary, the cooking method increase some physicochemical properties of tomato and facilitate the extraction of antioxidant compounds, in addition, griddling and frying seems to contribute positively to enhance the content of these phytochemicals and their antioxidant activity, despite the loss of vitamin C. So, the traditional cooking methods tested improve the nutritional properties of tomato fruit. Furthermore, we recommend the consumption of fresh tomato in order to provide some antioxidant compounds such as vitamin C and carotenoids which are very sensitive to heat treatment.

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