



Effects of ingredients and cooking time on total phenolic content and antioxidant activity of different homemade tomato sauces

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ABSTRACT

Tomato is one of the most consumed fruits in the world. Tomato sauce, a tomato product, is one of the mother sauces that has been developed by Escoffier (1846-1935). Nowadays, tomato sauce has been adapted by each country according to their own culinary culture. In the current study four different tomato sauce recipes were investigated in the context of their antioxidant activity and total phenolic content. Hydrophilic and lipophilic extractions of samples were evaluated separately. It was found that there is a relationship between total phenolic content and antioxidant activity in hydrophilic extraction. However, no similar correlation was found between total phenolic content and antioxidant activity in lipophilic extraction. According to the results, the highest antioxidant activity of both hydrophilic and lipophilic extractions was observed in S1 with the values 25.53 ± 1.01 and 45.48 ± 2.06 respectively. In lipophilic extraction, S2 had the lowest antioxidant activity with 32.77 ± 1.07 , because of the lack of the ingredients high in lipophilic antioxidant compounds. It was observed that the shortest cooking time with 10 min provide the highest retention of antioxidant activity and total phenolic content in this sauce. Also, antioxidant activity of lipophilic extraction for longer cooking time applied sauces (S4) could be kept high with ingredients such as carrot. It can be suggested that adding of ingredients which have antioxidant activity may be useful for providing bioactive properties in long cooking time procedures and it should be noted that the length of cooking time negatively affected the TPC values.

Keywords: Antioxidant activity, Cooking time, Gastronomy, Tomato sauces, Total phenolic component



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Introduction

Reactive oxygen species (ROS) play a key role in common diseases such as cancer, cardiovascular and neurodegenerative diseases and in aging by oxidizing the DNA, lipids and proteins (Corzo-Martínez et al., 2007). Plant based diets provide various phytochemicals which have antioxidant activity such as vitamin C and E, phenolic compounds and carotenoids (Dimitros, 2006). Phenolic compounds in vegetables constitute the major part of dietary antioxidants. Antioxidant activity of phenolic compounds results from scavenging free radicals (Nahak et al., 2014).

Tomato (*Solanum lycopersicum*), belonging to Solanaceae family, is one of the main ingredients of Western and Mediterranean diet (Martínez-Huélamo et al., 2015; Ricci et al., 2017; Tomas et al., 2017). Tomato and its products are important for human diet due to the high content of β -carotene, lycopene, flavonoids, ascorbic acid, vitamin E, folate and potassium (Hernández et al., 2007). These compounds are effective on scavenging ROS and to prevent formation of cancer cell lines by reducing cell proliferation (Kampa et al., 2000; Meyer et al., 2005). Beneficial health effects of some phytochemicals such as phenolics and carotenoids can reduce risk of various diseases such as cancer and cardiovascular diseases due to their antioxidant properties (Forbes-Hernandez et al., 2016; Tomas et al., 2017).

Tomato is generally consumed as fresh, canned, paste as an ingredient in food recipes (Knockaert et al., 2012). Georges Auguste Escoffier, one of the leader of Classical Cuisine, described the usage of tomato as sauce, grilled (tomatés grillés), stuffed with variable fillings (tomates farcies), fried (tomates frites), simmered with different ingredients (mousse de tomates), sauteed (tomates sautées), mashed (purée de tomates), mashed derivatives soufflé (soufflé de tomate) and reduced (tomato essence) in *Le Guide Culinaire*, first published in 1903, in which French cooking techniques explained by himself (Cracknell and Kauffman 2011). Among these types of usage, tomato sauce is one of the most consumed tomato products and Escoffier gained the “tomato sauce” to culinary world as one of the mother sauces.

Depending on culinary culture, tomato sauces are prepared by various different way in the world. Differences in ingredients, cutting and cooking techniques, cooking time and temperature provide the various sauces with different flavour, texture and bioactive properties. Ingredients of food and parameters of food processes such as temperature and time can affect the bioavailability (Arranz et al., 2015, Tomaş et al., 2019). For instance, oil existence in tomato product recipe enhances bioavailability of lipophilic carotenoids (Mozos et.al., 2018). Additionally, physical treatments on foods such

as chopping, slicing and mashing etc. may provide more extractable content of bioactive compounds such as lycopene (Sekin et al., 2005). Although some molecules such as carotenoids and organic acids become more accessible, thermo-sensitive components are negatively affected from thermal processing (Beltrán Sanahuja et al., 2019). On the other hand, adding ingredients which have antioxidant activity such as pepper, garlic or carrot may change the bioactive properties of tomato sauce.

In this study, four different homemade tomato sauces, which differ in their ingredients, cooking techniques and time, were selected as samples. Tomato was the main ingredient and garlic, green pepper and carrot were added as auxiliary materials into the recipes. It was aimed to investigate the effects of cooking time and ingredients on antioxidant properties and total phenolic content of tomato sauces.

Materials and Methods

Material

A commercial tomato variety (obtained from local producer in İstanbul) was used in the current study. The tomato sauce was prepared with different processing methods. Recipes and process flow chart of the sauces were shown in Table 1. Sauce preparation and analysis were repeated for three times.

Chemical Analysis

The moisture content, pH, titratable acidity, total water soluble solid were determined according to the Cemeroglu (2013). Sauces were analyzed in triplicate and mean values were reported.

Hydrophilic Extraction of Tomato Sauces

Hydrophilic extractions of tomato sauces were performed according to Capanoglu et al. (2008) with some modifications. 2 g of tomato sauce were homogenized with 5 mL of 75% aqueous methanol. The mixtures were shaken in shaking water bath (Mikrotest, mcs30) at room temperature for 30 min, then centrifuged (Hettich Universal, 32R) at 2700 rpm for 10 min and the supernatants were collected.

Lipophilic Extraction of Tomato Sauces

Lipophilic extractions of tomato sauces were performed according to Motilva et al. (2014) with some modifications. 5 g of tomato sauce was homogenized by stomacher (CLS Scientific, PM-174711) for 5 min with 10 mL of a mixture of acetone with 500 mL/L of ethanol. The mixture was centrifuged at 9500 rpm for 10 min and the supernatant was collected. This process was repeated twice and then all supernatants were combined. Organic solvent was evaporated, and residue

was dissolved in ethanol.

Antioxidant Activity Analysis

The antioxidant activity analysis was performed as described by Donkor et al. (2015). 200 μ L of extracts (hydrophilic and lipophilic) and 3800 μ L of 0.004% DPPH methanolic solution were mixed and the mixture were incubated at room temperature in a dark place for 60 minutes. After incubation, the absorbance of samples was measured at 517 nm (Thermo Scientific, Genesys 10S UV-Vis). Each sample were analysed in triplicate and % inhibition values were calculated as follows:

$$\% \text{Inhibition} = [(ABS_0 - ABS_1) / ABS_0] * 100$$

Here, ABS_0 is absorbance of 0.004% DPPH solution without sample and ABS_1 is absorbance of samples and DPPH solution mixture.

Total Phenolic Compound

Total phenolic compound analysis was performed according to Singleton and Rossi (1965). 100 μ L of extract and 900 μ L of distilled water were mixed and then 5 mL of Folin-ciocalteu solution was added. 3 minutes later 4 mL of Na_2CO_3 was added and the mixture was incubated at room temperature in a dark place for 2 hours. After incubation, the absorbance of

samples was measured at 765 nm. Each sample were analysed in triplicate and total phenolic compound were given as mg/kg gallic acid.

Statistical Analysis

Data were analysed by SPSS software (ver. 23 SPSS Inc., Chicago, IL, USA). ANOVA and Tukey's mean comparison test at a significance level of 5% were used for statistical analysis. Correlation analysis were carried out with Pearson's Correlation Analysis by SPSS.

Results and Discussion

Moisture contents, pH, total water soluble solid (brix) and titratable acidity of samples were given at Table 2. In the current study, moisture contents of tomato sauces were found to be 80.18 ± 1.9 for S1, 83.69 ± 1.00 for S2, 63.19 ± 9.21 for S3 and 85.27 ± 0.01 for S4. Moisture content of home processed, and industrial processed tomato sauce were determined as 91.0 ± 0.8 and 89.0 ± 0.8 , respectively by Tomas et al. (2017). Cooking time and temperature may be responsible for these different reductions. Although S4 has the longest cooking time, its moisture content was not found to be the lowest because that liquid content was much more than other recipes.

Table 1. Tomato Sauce Recipe and Preparation

Tomato Sauce	Recipe	Preparation	Total Cooking Time
S1	Tomato (1 kg, mire-poix) Green pepper (100 g, brunoise) Extra virgin olive oil (20 mL) Salt (3 g)	Heat the oil Sauté the green peppers and tomatoes Add salt Bring boil Remove from heat	10 min
S2	Tomato (1 kg, brunoise) Green pepper (100 g, brunoise) Garlic (2 cloves) Extra virgin olive oil (20 mL) Salt (3 g)	Sauté the garlic and green pepper in olive oil Add tomatoes Simmer for 15 minutes Add salt and simmer for 5 minutes by stirring	20 min
S3	Tomato (1 kg, mashed) Garlic (4 cloves, brunoise) Extra virgin olive oil (20 mL) Salt (3 gr)	Heat the olive oil Sauté garlic Add tomatoes and salt Simmer for 30 minutes Remove from heat when sauce is stiffen	30 min
S4	Tomato (1 kg, mire-poix) Garlic (1 cloves, brunoise) Carrot (200 g, grated) Extra virgin olive oil (20 mL) Salt (3 g) Water (1 L)	Sauté garlic and carrots Add tomato, salt and water Simmer for 2 hours	2 hours

Total phenolic contents (TPC) of sauces were presented in Table 3. TPC values were ranged from 340.19 to 706.14 mg/kg gallic acid for hydrophilic extraction and 61.61 to 196.68 mg/kg gallic acid for lipophilic extraction. It was fact that TPC obtained from hydrophilic extraction of S1 was found to be the highest among the all sauce samples. Differences in TPC may be explained with ingredients variation, cooking time and techniques and different cutting techniques. Although garlic was added into the S2 and S3 recipe, TPC value was found to be higher in S1 due to shortest cooking time. Gorinstein et al. (2009) showed that TPC and antioxidant activity decreased with the increment of cooking time. Vallejo et al. (2003) also demonstrated that prevention of bioactive compounds losses in broccoli could be provided with the shortest heat treatment time and indicated that during domestic cooking, phenolic compound degradation can enhance or chemical changes which affect the quality parameters can produce. Likewise, Wachtel-Galor et al. (2008) reported that total phenolic content decreased with the increment of cooking time regardless the cooking technique. Additionally, Buchner et al. (2006) indicated that phenolic compounds, that are heat sensitive, could degrade during cooking time.

On the other hand, TPC extracted by lipophilic solvent varied. The highest lipophilic TPC was obtained from S4 (99.19 mg/kg gallic acid). Likewise, hydrophilic extraction, variation of lipophilic extraction may result from preparation method, ingredients and cutting techniques.

Antioxidant activity in tomato is originated from carotenoids, polyphenols, flavonoids and ascorbic acid (Gahler et al., 2003). Antioxidant activity was determined separately for hydrophilic extracts and lipophilic extracts of samples by using DPPH method. Antioxidant activity of hydrophilic extractions were found to be 25.53%, 22.47%, 19.14%, 13.59% for S1, S2, S3 and S4, respectively. Antioxidant activity was also in a relationship between total phenolic content for hydrophilic extraction ($p < 0.05$) and increased with the increment in total phenolic content. Pearson's correlation (r) between TPC and antioxidant activity in hydrophilic extraction was found to be 0.982.

As seen from Table 3, antioxidant activity of lipophilic extracts was significantly higher than hydrophilic extracts ($p < 0.05$). Main source of antioxidant activity in lipophilic extractions is carotenoids because of their lipophilic character. During food process, phytochemicals which have additive or synergistic effects on antioxidant activity could be released from food matrix (Dewanto et al., 2002). Due to thermal process, cell walls may be broken down and the bonds between lycopene and tissue matrix weak (Dewanto et al., 2002 and Chang et al., 2006), thus bioavailability of lycopene and correspondingly antioxidant activity could increase. Additionally, enzymatic degradation, resulting from heating process, increase the carotenoid content because of weakening in protein-carotenoid aggregates (Stahl and Sies, 1992; Sahlin et al., 2004).

Table 2. Chemical Analysis of Tomato Sauces (Means \pm Standard deviation)

Sample name	%Moisture	Brix	Titrateable acidity	pH
S1	80,18 \pm 1,9 ^a	8,05 \pm 0,1 ^a	0,35 \pm 0,01 ^a	4,66 \pm 0,03 ^a
S2	83,69 \pm 1,00 ^a	7,21 \pm 0,01 ^b	0,38 \pm 0,1 ^a	4,71 \pm 0,05 ^a
S3	63,19 \pm 9,21 ^b	10,03 \pm 0,1 ^c	0,51 \pm 0,02 ^b	4,63 \pm 0,01 ^a
S4	85,27 \pm 0,01 ^a	7,02 \pm 0,2 ^{bd}	0,21 \pm 0,02 ^c	5,01 \pm 0,05 ^b

^{a,b,c,d} Different letters in the same column indicate statistical difference ($p < 0.05$)

Table 3. Total Phenolic Content and Antioxidant Activity of Tomato Sauces

Sample name	Total phenolic content (mg/kg gallic acid)		Antioxidant capacity (%DPPH inhibition)	
	Hydrophilic Extraction	Lipophilic Extraction	Hydrophilic Extraction	Lipophilic Extraction
S1	706.14 \pm 5.04 ^{aA}	72.63 \pm 3.03 ^{aB}	25.53 \pm 1.01 ^{aA}	45.48 \pm 2.06 ^{aB}
S2	635.23 \pm 7.33 ^{bA}	76.68 \pm 7.41 ^{aB}	22.47 \pm 1.04 ^{bA}	32.77 \pm 1.07 ^{bB}
S3	457.18 \pm 4.61 ^{cA}	61.61 \pm 3.10 ^{bB}	19.14 \pm 1.03 ^{bA}	33.63 \pm 1.05 ^{bB}
S4	340.19 \pm 3.05 ^{dA}	99.19 \pm 5.55 ^{cB}	13.59 \pm 1.07 ^{cA}	35.58 \pm 1.25 ^{bB}

^{a,b,c,d} Different letters in the same column indicate statistical difference ($p < 0.05$)

^{A,B} Different uppercase letters in the same row indicate statistical difference between hydrophilic and lipophilic extraction ($p < 0.05$)

The highest lipophilic and hydrophilic antioxidant activity was observed in S1 in this study. When considering the sauce preparation methods (Table 1) used in this study, S1 has minimum cooking time. Seybold et al. (2004) indicated that the shorter heating time provide the higher α -tocopherol contents in tomato sauces. Yilmaz and Toledo (2005) stated that long heating time can cause the decrement in antioxidant activity of products due to melanoidin and polyphenol degradation. Although hydrophilic phenolic content of S1 was higher than lipophilic phenolic content, antioxidant activity of lipophilic extraction was observed higher than hydrophilic extraction. It may be explained with higher carotenoid and tocopherol content of lipophilic extraction (Bae et al., 2012). Likewise, Bae et al. (2012) have reported that non-polar and mid polar extracts showed higher antioxidant activity than polar extracts in different peppers. On the other hand, S4 showed the lowest antioxidant activity by hydrophilic extraction, while the highest antioxidant activity was obtained from S1. It was thought that longer cooking time could reduce compounds that have antioxidant properties. In contrast to hydrophilic extraction, lipophilic extraction could be affected by many variations such as carotenoids and tocopherols as well lipophilic phenolics. In contrast to hydrophilic extraction, poor correlation coefficient was found between antioxidant activity and TPC in lipophilic extraction ($r = -0.468$) as lipophilic compounds have important role in antioxidant activity of lipophilic extracts as well TPC. It was fact that S1 had the highest antioxidant activity in lipophilic extraction, while S2 had the lowest antioxidant activity. These differences could result from ingredients being source of lipophilic antioxidant compounds and preparation methods. Although S4 has the highest cooking time, high lipophilic antioxidant activity may be caused from carrot.

Conclusion

This study has importance for culinary science in terms of bioactive properties of different tomato sauces. In the current study, comparison of total phenolic content and antioxidant activity of four different tomato sauces were investigated in hydrophilic and lipophilic extraction. Antioxidant activity of sauce samples was significantly affected by cooking time, ingredient variation and preparation method. Additionally, lipophilic extracts showed higher antioxidant activity than hydrophilic extracts due to probably lipophilic antioxidant content. Moreover, antioxidant activity was significantly correlated with TPC in hydrophilic extracts. On the contrary, poor correlation coefficient was found between antioxidant activity and TPC in lipophilic extraction as lipophilic compounds have important role in antioxidant activity of lipophilic extracts as well TPC. It has been suggested that adding of ingredients which have antioxidant activity may be useful for

providing bioactive properties in long cooking time procedures.

Compliance with Ethical Standard

Conflict of interests: The authors declare that for this article they have no actual, potential or perceived the conflict of interests.

Ethics committee approval: Author declare that this study does not include any experiments with human or animal subjects.

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Disclosure: -

References

- Arranz, S., Martinez-Huelamo, M., Vallverdu-Queralt, A., Valderas-Martinez, P., Illan, M., Sacanella, E., Escribano, E., Estruch R., Lamuela-Raventos, R.M. (2015). Influence of olive oil on carotenoid absorption from tomato juice and effects on postprandial lipemia. *Food Chemistry*, 168, 203-210.
<https://doi.org/10.1016/j.foodchem.2014.07.053>
- Bae, H., Jayaprakasha, G. K., Jifon, J., Patil, B. S. (2012). Variation of antioxidant activity and the levels of bioactive compounds in lipophilic and hydrophilic extracts from hot pepper (*Capsicum* spp.) cultivars. *Food chemistry*, 134(4), 1912-1918.
<https://doi.org/10.1016/j.foodchem.2012.03.108>
- Beltrán Sanahuja, A., De Pablo Gallego, S. L., Maestre Pérez, S. E., Valdés García, A., & Prats Moya, M. S. (2019). Influence of cooking and ingredients on the antioxidant activity, phenolic content and volatile profile of different variants of the mediterranean typical tomato sofrito. *Antioxidants*, 8(11), 551.
<https://doi.org/10.3390/antiox8110551>
- Buchner, N., Krumbein, A., Rohn, S., & Kroh, L. W. (2006). Effect of thermal processing on the flavonols rutin and quercetin. *Rapid Communications in Mass Spectrometry: An International Journal Devoted to the Rapid Dissemination of Up-to-the-Minute Research in Mass Spectrometry*, 20(21), 3229-3235.
<https://doi.org/10.1002/rcm.2720>

- Capanoglu, E., Beekwilder, J., Boyacioglu, D., Hall, R. & De Vos, C.H.R. (2008). Changes in antioxidants and metabolite profiles during production of tomato paste, *Journal of Agricultural and Food Chemistry*, 56(3), 964-973. <https://doi.org/10.1021/jf072990e>
- Cemeroğlu, B. (2013). *Gıda analizleri* (Editor: Cemeroğlu, B.). Bizim Büro Basımevi, ISBN: 9786056341939.
- Chang, C.H., Lin, H.Y., Chang, C.Y., Liu, Y.C. (2006). Comparisons on the antioxidant properties of fresh, freeze-dried and hot-air-dried tomatoes, *Journal of Food Engineering*, 77(3), 478-485. <https://doi.org/10.1016/j.jfoodeng.2005.06.061>
- Corzo-Martínez, M., Corzo, N., Villamiel, M. (2007). Biological properties of onions and garlic. Trends in food science & technology, 18(12), 609-625. <https://doi.org/10.1016/j.tifs.2007.07.011>
- Cracknell, H.L., Kaufmann, R., J. (2011). Escoffier Le Guide Culinaire. 2nd edition. John Wiley&Sons Inc., ISBN: 978-0470900277.
- Dewanto, V., Wu, X., Adom, K.K. & Liu, R.H., (2002). Thermal processing enhances the nutritional value of tomatoes by increasing total antioxidant activity, *Journal of Agricultural and Food Chemistry*, 50, 3010-3014. <https://doi.org/10.1021/jf0115589>
- Dimitrios, B. (2006). Sources of natural phenolic antioxidants. *Trends in Food Science & Technology*, 17(9), 505-512. <https://doi.org/10.1016/j.tifs.2006.04.004>
- Donkor, S., Agyekum, A.K., Akuamoah, F., Adu-Bobi, N.A.K., Achel, D.G., Asare, I.K., Kyei, J. (2015). Antioxidant potentials of tomato paste extracts found on major markets in Accra Metropolis. *American Journal of Applied Chemistry*, 3(5):158-163. <https://doi.org/10.11648/j.ajac.20150305.11>
- Forbes-Hernandez, T. Y., Gasparrini, M., Afrin, S., Bompadre, S., Mezzetti, B., Quiles, J. L., Giampieri F. & Battino, M. (2016). The healthy effects of strawberry polyphenols: which strategy behind antioxidant capacity? *Critical Reviews in Food Science and Nutrition*, 56(sup1), S46-S59. <https://doi.org/10.1080/10408398.2015.1051919>
- Gahler, S., Otto, K., Böhm, V. (2003). Alterations of vitamin C, total phenolics, and antioxidant capacity as affected by processing tomatoes to 137 different products, *Journal of Agricultural and Food Chemistry*, 51, 7962-7968. <https://doi.org/10.1021/jf034743q>
- Gorinstein, S., Jastrzebski, Z., Leontowicz, H., Leontowicz, M., Namiesnik, J., Najman, K., Park, Y.S., Heo, B.G., Cho, J.Y., Bae, J.H. (2009). Comparative control of the bioactivity of some frequently consumed vegetables subjected to different processing conditions. *Food Control*, 20(4), 407-413. <https://doi.org/10.1016/j.foodcont.2008.07.008>
- Hernández, M., Rodríguez, E., Díaz, C. (2007). Free hydroxycinnamic acids, lycopene, and color parameters in tomato cultivars. *Journal of Agricultural And Food Chemistry*, 55, 8604-8615. <https://doi.org/10.1021/jf071069u>
- Kampa, M., Hatzoglou, A., Notas, G., Damianaki, A., Bakogeorgou, E., Ge-metzi, C., Kouroumalis, E., Martin, P.M. & Castanas, E. (2000). Wine antioxidant polyphenols inhibit the proliferation of human prostate cancer cell lines. *Nutrition and Cancer*, 37(2), 223–233. https://doi.org/10.1207/S15327914NC372_16
- Knockaert, G., Pulissery, S. K., Colle, I., Van Buggenhout, S., Hendrickx, M., & Van Loey, A. (2012). Lycopene degradation, isomerization and in vitro bioaccessibility in high pressure homogenized tomato puree containing oil: Effect of additional thermal and high pressure processing. *Food Chemistry*, 135(3), 1290–1297. <https://doi.org/10.1016/j.foodchem.2012.05.065>
- Martínez-Huélamo, M., Tulipani, S., Estruch, R., Escribano, E., Illán, M., Corella, D., & Lamuela-Raventós, R.M. (2015). The tomato sauce making process affects the bioaccessibility and bioavailability of tomato phenolics: A pharmacokinetic study. *Food Chemistry*, 173, 864-872. <https://doi.org/10.1016/j.foodchem.2014.09.156>
- Meyer, F., Galan, P., Douville, P., Bairati, I., Kegle, P., Bertrais, S., Estaquio C., Hercberg, S. (2005). Antioxidant vitamin and mineral supplementation and prostate cancer prevention in the SU.VI.MAX trial. *International Journal of Cancer*, 116(2), 182–186. <https://doi.org/10.1002/ijc.21058>
- Motilva, M.J., Maciá, A., Paz-Romero, M., Labrador, A., Domínguez, A., Peiró, L. (2014). Optimisation and validation of analytical methods for the simultaneous extraction of

antioxidants: Application to the analysis of tomato sauces. *Food Chemistry*, 163, 234-243.

<https://doi.org/10.1016/j.foodchem.2014.04.096>

Mozos, I., Stoian, D., Caraba, A., Malainer, C., Horbañczuk, J.O., Atanasov, A.G. (2018). Lycopene and Vascular Health. *Frontiers in Pharmacology*, 9, 521.

<https://doi.org/10.3389/fphar.2018.00521>

Nahak, G., Suar, M., Sahu, R. K. (2014). Antioxidant potential and nutritional values of vegetables: a review. *Research Journal of Medicinal Plants*, 8(2), 50-81.

<https://doi.org/10.3923/rjmp.2014.50.81>

Ricci, A., Antonini, E., Ninfali, P. (2017). Homemade Tomato Sauce in the Mediterranean Diet: A Rich Source of Antioxidants. *Italian Journal of Food Science*, 30(1).

<https://doi.org/10.14674/IJFS-980>

Sahlin, E., Savage, G.P., Lister, C.E. (2004). Investigation of the antioxidant properties of tomatoes after processing, *Journal of Food Composition and Analysis*, 17, 635–647.

<https://doi.org/10.1016/j.jfca.2003.10.003>

Sekin, Y., Bağdatlıoğlu, N., & Kirdinli, Ö. (2005). Domates konservesi üretiminde çeşitli faktörlerin likopen niceliğine etkisi. *Celal Bayar Üniversitesi Fen Bilimleri Dergisi*, 1(1), 7-14.

<https://doi.org/10.18466/cbufbe.35354>

Seybold, C., Fröhlich, K., Bitsch, R., Otto, K. & Böhm, V., (2004). Changes in contents of carotenoids and vitamin E during tomato processing, *Journal of Agricultural and Food Chemistry*, 52, 7005-7010.

<https://doi.org/10.1021/jf049169c>

Singleton, V.L., Rossi, J.A., (1965). Colorimetry of total

phenolics with phosphomolybdic-phosphotungstic acid reagents, *American Journal of Enology and Viticulture*, 16, 144.

Stahl, W., Sies, H., (1992). Uptake of lycopene and its geometrical isomers is greater from heat-processed than from unprocessed tomato juice in humans, *Journal of Nutrition*, 122, 2161-2166.

<https://doi.org/10.1093/jn/122.11.2161>

Tomas, M., Beekwilder, J., Hall, R. D., Sagdic, O., Bo-yacioglu, D., Capanoglu, E. (2017). Industrial processing versus home processing of tomato sauce: Effects on phenolics, flavonoids and in vitro bioaccessibility of antioxidants. *Food Chemistry*, 220, 51-58.

<https://doi.org/10.1016/j.foodchem.2016.09.201>

Tomaş, M., Sağdıç, O., Çatalkaya, G., Kahveci, D., Çapanoğlu, E. (2019). Effects of cooking and extra virgin olive oil addition on bioaccessibility of carotenenes in tomato sauce. *Turkish Journal of Agriculture and Forestry*, 43.

<https://doi.org/10.3906/tar-1801-127>

Vallejo, F., Tomás-Barberán, F. A., & García-Viguera, C. (2003). Phenolic compound contents in edible parts of broccoli inflorescences after domestic cooking. *Journal of the Science of Food and Agriculture*, 83(14), 1511-1516.

<https://doi.org/10.1002/jsfa.1585>

Wachtel-Galor, S., Wong, K.W., Benzie, I.F. (2008). The effect of cooking on Brassica vegetables. *Food chemistry*, 110(3), 706-710.

<https://doi.org/10.1016/j.foodchem.2008.02.056>

Yilmaz, Y., Toledo, R. (2005). Antioxidant activity of water-soluble Maillard reaction products. *Food Chemistry*, 93(2), 273–278.

<https://doi.org/10.1016/j.foodchem.2004.09.043>