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Research

Effect of Cooking Method on The Physicochemical Properties of Tomatoes

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ABSTRACT

The cooking process influences the chemical and physical changes in food due to the increase in temperature. It also alters the appearance, taste, color, and texture of food either positively or negatively. Therefore, this study was done to determine the effect of cooking methods on the physicochemical properties and the retention of antioxidant content in tomatoes. The cooking conditions used were boiling at 100°C for 6 min, frying at 230°C for 4.5 min, baking at 175°C for 25 min, and cooking with an air fryer at 200°C for 15 min. Physicochemical characteristics (cooking loss, ash, crude fiber, firmness, color, pH value & total soluble solids) were measured. Antioxidant properties (antioxidant activity, total phenolic content, lycopene content, and ascorbic acid content) were also determined. There were significant differences ($p<0.05$) for ash, color, pH value, and total soluble solid, while no significant difference ($p>0.05$) was observed for cooking loss, crude fiber, and firmness. Different cooking methods had shown a significant difference ($p<0.05$) against all tests for determining antioxidant activity, total phenolic content, lycopene content, and ascorbic acid content. Air frying is the best cooking method to preserve the physicochemical properties of tomatoes, compared to other methods employed. Hence, it can be concluded that different cooking methods have different effects on the physicochemical properties of tomatoes.

Key words: Antioxidant, cooking method, physicochemical properties, tomatoes

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INTRODUCTION

Cooking is defined as the transfer of energy from a heat source to food. This heat energy can bring changes to the molecular structure of food. There are several cooking methods such as blanching, boiling, baking, grilling and even frying that are often used to craft nutritious and well-balanced meals (Lee *et al*., 2018). The effects of heat released from the cooking process can affect the nutritional value of food (Thanuja *et al*., 2019). Cooking also has an effect in changing the appearance, taste, color, and texture of food either positively or negatively due to the increase in temperature. This is because the increase in temperature can maintain or reduce the nutrition found in food and cause the formation of toxic compounds (Lee *et al*., 2018).

However, there are also benefits of cooking that cannot be ignored, namely increased food safety, increased nutritional value, and the formation or release of phytochemical compounds (Zhao *et al*., 2019). Additionally, the heat produced during cooking can break down the cell walls of vegetables such as tomatoes and result in a softer texture and enhanced flavor. This change in texture can be beneficial in various dishes such as sauces and soups (Ochida *et al*., 2018). Increasing the temperature during cooking can also facilitate the extraction of bioactive compounds such as carotenoids and polyphenols that can contribute to overall nutritional value (Melini *et al*., 2019).

Tomatoes are widely consumed and provide significant nutritional benefits. However, the way tomatoes are cooked can significantly impact their physicochemical properties, which in turn can affect their nutritional value, taste, texture, and health benefits. In general, tomatoes are often cooked using different cooking methods such as boiling, frying, and baking. Different cooking processes bring different changes to the physicochemical characteristics of tomatoes (Berinyuy *et al*., 2018). Information about the effect of the cooking method is still lacking on the physicochemical properties and retention of antioxidant activity in tomatoes (Berinyuy *et al*., 2018; Beltrán Sanahuja *et al*., 2019; Azali *et al*., 2022). The increase in temperature through the cooking process will bring heat effects and cause changes in appearance, taste, texture, and bioactive compounds found in tomatoes. Therefore, in this study, several cooking methods were employed to evaluate and determine the physicochemical characteristics and retention of antioxidant content in tomatoes.

MATERIALS AND METHODS

Sample preparation

Medium-size fresh red tomatoes (*Lycopersicon esculentum* Mill.) were purchased from Jaya Grocer, Bangi Gateway, Bangi, Selangor, Malaysia. The maturity was determined and selected at level 5 (fully ripe) according to the tomato maturity index based on the Malaysian Standard MS393:2010. Tomatoes were cleaned using tap water and cut in half. The samples were ensured to have the same size and shape for all treatments. Tomatoes were cooked in four different conditions: boiled (at 100°C for 6 min) (Maqbool *et al*., 2021), fried (at 230°C for 4.5 min), baked (at 175°C for 25 min) (Arkoub-Djermoune *et al*., 2019) and air fried (at 200°C for 15 min) (Maqbool *et al*., 2021). All analyses were performed in three replications.

Physicochemical properties

Cooking loss

Cooking loss (%) was calculated using the following formula = ((weight before cooking in g - weight after cooking in g) / weight before cooking in g) × 100 (Kim *et al*., 2022).

Ash content

The ash content was determined based on the method of Manjula *et al*. (2023). A total of 5 g samples were put into a porcelain crucible and burned in an ash furnace at 450-550°C overnight and then cooled to room temperature in a desiccator. The porcelain crucible containing the ash was weighed and the weight of the porcelain crucible was recorded, and results are expressed in %.

Crude fiber

Crude fiber content was determined through digestion with acid and alkali (Ogofure & Ologbosere, 2023), by digesting 3 g of sample (with 1.25% H_2SO_4, 1.25% NaOH, and 1% HCl) and incinerating the residue at 450 to 550°C overnight. Results are expressed in %.

Firmness

Firmness was measured using a probe-type (probe with cylindrical tip) texture analysis tool (AGS-500NJ, Shimadzu, Japan) (Olveira-Bouzas *et al*., 2021). A speed of 2 mms^{-1} and a penetration distance of 10 mm were used. The resistance to the applied force is expressed in Newton.

pH value

The pH value was measured using a pH meter. The electrode of the pH meter was placed into the homogeneous liquid of the tomato sample and the pH reading was obtained and recorded (Huang *et al*., 2018).

Total soluble solid

The total soluble solid was measured by using a refractometer (TDJ-050 atc, Shenzhen Yago Technology Limited, China) at 0° to 50° (Nemeskéri *et al*., 2019). The refractometer was calibrated to 0 °Brix using distilled water. The cooked tomato samples were ground to obtain juice. Then, a few drops of filtered tomato juice were placed on the refractometer prism. The value obtained is interpreted as °Brix.

Color

Color was measured using a colorimeter (Chroma Meter CR-400, Minolta Co., Japan) with the L*(brightness), a* (redness), and b* (yellowish) parameters.

Antioxidant properties

Sample extraction

A total of 2 g of the homogenized sample was extracted with 50 mL of 80% methanol and then centrifuged at 2200 rpm for 15 min at room temperature. The supernatant was stored at 4°C to determine antioxidant activity and total phenolic content (Maqbool *et al*., 2021).

Antioxidant activity

The antioxidant activity in sample extracts was measured using the 2,2-diphenyl-2-picrihydrazyl (DPPH) free radical scavenging test (Mahieddine *et al*., 2018). A 10 ppm (mg/mL) ascorbic acid stock solution was used to prepare serial dilutions containing 2, 4, 6, 8, and 10 ppm ascorbic acid. A 0.01% DPPH reagent solution was prepared and covered with aluminum foil. A total of 500 µL sample extract was mixed with 500 µL 0.01% DPPH reagent solution. The mixture was shaken vigorously and left at room temperature for 30 min. Absorbance was measured and read at 517 nm using a spectrophotometer. Antioxidant activity (%) = ((Absorption of control−Absorption of sample)/Absorption of control) ×100

Total phenolic content

The total phenolic content of the extract was determined (Thanuja *et al*., 2019). A 100 ppm (mg/mL) gallic acid stock solution was used to prepare serial dilutions containing 20, 40, 60, 80, and 100 ppm gallic acid. A total of 200 µL of the extracted sample was mixed with 1 mL of Folin-Ciocalteau reagent solution and left at room temperature for 5 min. A total of 800 µL of 6% sodium carbonate (w/v) was added to the mixture and shaken. After being left at room temperature for 30 min, the absorbance was read at 765 nm using a UV-Vis spectrophotometer against a blank reagent that was using 300 µL of 70% ethanol. The total phenolic content was calculated from a standard curve using gallic acid (Nasir *et al*., 2021). Results are expressed in % using the following calculation = (reading from the standard curve × dilution factor × total volume) / (sample volume ×sample weight ×10000).

Lycopene content

Based on the method described in Mahieddine *et al*. (2018), 1 g of the sample was homogenized with 4 mL of hexane/ethanol/acetone (2/1/1, v/v), placed on the rotary mixer (30 min), and then added with 10 mL of distilled water. The sample extract was left for 5 min and the absorbance was measured spectrophotometrically at 503 nm. Lycopene content is expressed as mg/kg of original weight. The calculation is based on the following equation:

Lycopene content = Absorption (503 nm) × 137.4 (constant coefficient).

Ascorbic acid content

A total of 1 g of sample was extracted using 20 mL of 3% metaphosphoric acid (w/v) and then shaken at 300 rpm for 30 min using a shaker (Nkolisa *et al*., 2019). The sample extract was centrifuged at 4000 rpm for 10 min at 4°C. Ascorbic acid content was determined using the 2,6-dichlorophenolindophenol (DCPIP) method. A total of 1 mL of sample extract was added and mixed with 3 mL of 0.2 mM DCPIP. After 15 sec, absorbance was measured using a spectrophotometer at 515 nm. The ascorbic acid value obtained is expressed as mg of ascorbic acid/100 g fresh sample weight based on the standard curve.

Statistical analysis

All analyses were performed in three replications. All data obtained were analyzed with analysis of variance (ANOVA) and Tukey test to test for any differences between samples, performed using Minitab software version 17.0 at a confidence level of 95% (p<0.05).

RESULTS AND DISCUSSION

Physicochemical properties

Cooking loss

Table 1 shows the cooking loss of tomato samples subjected to different cooking treatments with no significant difference (p>0.05) overall. Cooking loss of heat treatment occurs due to loss of moisture (Vujadinović *et al*., 2014). This is consistent with previous studies that show different cooking methods do not provide different observations on the moisture content (Martínez-Hernández *et al*., 2016; Arkoub-Djermoune *et al*., 2016; De Santiago *et al*., 2018). This is because cooking promotes the removal of water and subsequently causes a reduction in moisture. Additionally, heat and mass transfer occur during cooking and cause temperature and moisture gradients in the tomato sample. This heat transfer increases the temperature of the tomato sample and leads to the breakdown of the cell wall, a decrease in moisture content, and a change in the texture and flavor (Lewicki, 1998).

Table 1. Cooking loss, ash, crude fiber, firmness, pH value, and total soluble solid of tomato undergoing different cooking treatments

Cooking method	Cooking loss (%)	Ash (%)	Crude Fiber (%)	Firmness (N)	pH value	Total Soluble Solid (°Brix)
Boiled (100°C, 6 min)	40.47 ± 1.92[a]	0.66 ± 0.01[b]	53.27 ± 3.63[a]	0.17 ± 0.10[a]	4.53 ± 0.11[a]	4.33 ± 0.58[c]
Fried (230°C, 4.5 min)	38.49 ± 2.09[a]	0.23 ± 0.02[b]	52.06 ± 4.72[a]	0.19 ± 0.08[a]	4.50 ± 0.04[ab]	6.50 ± 0.50[b]
Baked (175°C, 25 min	39.73 ± 1.18[a]	0.20 ± 0.05[b]	54.96 ± 0.99[a]	0.18 ± 0.08[a]	4.38 ± 0.02[ab]	7.67 ± 0.29[ab]
Air fried (200°C, 15 min)	37.03 ± 2.06[a]	1.18 ± 0.3[a]	52.97 ± 5.95[a]	0.20 ± 0.09[a]	4.35 ± 0.04[b]	8.17 ± 0.76[a]

[a-c] Different letters indicate significant differences (p<0.05), within the same column.

Ash content

Ash content refers to the total quantity of minerals found in the sample. The ash content of the samples (Table 1) showed a significant difference (ANOVA p<0.05) overall. According to the Malaysian Food Composition Database (MyFCD 2023), the ash content of fresh tomatoes is 0.6%. The method of frying with an air fryer shows the highest value of ash content significantly (p<0.05) which is 1.18 ± 0.31% compared to other cooking methods. This can be explained by the study of Arkoub-Djermoune *et al*. (2019), which showed that dry cooking methods such as grilling and baking cause an increase in the amount of minerals compared to wet cooking methods that cause mineral release in water and frying oil. The increase in the amount of this mineral was also proven by Lopes *et al*. (2015) in other vegetables, namely kale and cabbage because cell wall disruption causes protein denaturation and release of organic acids.

Crude fiber

The crude fiber content of tomato samples (Table 1) ranged from 0.23% to 0.88% and did not show a significant difference (p>0.05) overall. According to MyFCD (2023), the crude fiber content of fresh tomatoes is 0.5%. Compared to MyFCD (2023) data on fresh tomatoes, the crude fiber content of tomato samples changed after undergoing different cooking treatments. There is an increase in crude fiber content by using the frying method and the air fryer method. This increase may be due to hydration or fractional polymerization in tomato samples (Kala & Prakash, 2004). Not only that, increasing the temperature during cooking can break the bond between polysaccharides and split glycosidic bonds, thus increasing the dissolution of crude fiber in tomatoes (Abdalla & Yousef, 2016).

Meanwhile, there is a decrease in crude fiber content by using boiling and baking methods. When tomatoes are cooked, the heat produced causes the cell walls to break down, and the crude fiber presents in the tomatoes make them softer and easier to digest. The breakdown of this cell wall results in a reduction in crude fiber content (Ruiz-Rodriguez *et al*., 2008). The results of this study are also consistent with observations in other vegetables, namely white cabbage (Wennberg *et al*., 2003). However, Rodríguez *et al*., (2006) reported an increase in crude fiber during boiling due to complex formation between polysaccharides and other compounds such as proteins.

Firmness

The firmness values of tomato samples ranged from 0.17 to 0.20 and did not show a significant difference (p>0.05) overall. The results of this study are consistent with other vegetables, namely cauliflower (Nartea *et al*., 2021). The heat during cooking causes the breakdown of the tomato cell walls and causes the fruit to soften. This heat affects the structure of pectin, a complex carbohydrate found in the cell wall that contributes to the softening of tomatoes (Barbagallo *et al*., 2009; Nartea *et al*., 2021).

pH value

Analysis of the pH value (Table 1) showed a significant difference (ANOVA p<0.05) overall. In this study, the pH range of each sample that underwent different cooking methods is between 4.38 - 4.53. Based on Huang *et al*. (2018), the normal pH range in tomatoes is between 4.0 to 4.3. In this study, it was found that the boiling method recorded the highest pH value significantly (p<0.05) with a reading of 4.53 ± 0.11 while the air frying method recorded the lowest pH value significantly (p<0.05) with a reading of 4.35 ± 0.04.

According to Arkoub-Djermoune *et al*. (2019), the pH value of fresh tomatoes was 4.15 ± 0.01 and it was found that the pH value of tomatoes increased after cooking. The increase in tomato pH is due to the extraction of organic acids when the tomato cell walls soften after cooking. Not only that, the increase in pH is also due to the reduction of carboxylic groups in proteins during cooking (Gök & Bor, 2016). Based on the study of Razzak *et al*. (2023) on other vegetables namely carrots and spinach, the boiling method resulted in an increase in pH compared to the cooking method. Boling promotes the degradation of heat-sensitive acids the reduction of active carboxylic groups in proteins and the release of calcium and magnesium ions from proteins.

Total soluble solid

The most important soluble solid in vegetables is sugar. Other components include minerals, amino acids, and even vitamins. The total soluble solids estimation is used to determine the sugar content in fruits and vegetables as well as the concentration of monosaccharides and disaccharides (Cejpek, 2012). The results of total soluble solids (Table 1) in this study ranged from 4.33 °Brix to 8.17 °Brix and showed a significant difference (p<0.05) between groups. The method of frying with an air fryer recorded the highest value significantly (p<0.05) (8.17 ± 0.76 °Brix), but not significantly different (p>0.05) from the method of baking. The boiling method (4.33 ± 0.58 °Brix) recorded the lowest value significantly (p<0.05) compared to other treatments.

The findings of this study are consistent with the study of Arkoub-Djermoune *et al*. (2019) (ranges from 4.23 °Brix to 8.33 °Brix). This increase in dissolved solids is caused by water loss and increased sugar concentration in tomato samples (dos Reis *et al*., 2015). In this study, boiling recorded the lowest value of total soluble solids. Similarly, boiling causes lower losses of soluble solids in other vegetables, namely kale and red cabbage (Armesto *et al*., 2017). Heat production during cooking can cause the breakdown of cell walls and changes in the physical properties of tissues that contribute to the loss of dissolved solids (Martínez *et al*., 2013). This loss is due to the diffusion of soluble compounds into the water (Armesto *et al*., 2017). The increasing trend from boiling to air-frying is primarily due to the reduction in water content and the concentration of soluble solids. Higher temperature methods (frying, baking, and air-frying) are more efficient at removing water, which significantly increases the total soluble solids compared to boiling.

Color

Color is a very important attribute of tomatoes because it is an attribute used by consumers to evaluate the quality of tomatoes (Jürkenbeck *et al*., 2020). Based on Table 2, the L* value for all tomato samples is in the range of 34.85 - 55.72. and shows a significant difference (ANOVA p<0.05) overall. The frying method recorded the lowest L* value which is 34.85 ± 2.19. The results of this study are similar to those in the study by Delgado-Andrade *et al*., (2010). This is because the method of frying involves the Maillard reaction, which is a chemical reaction between amino acid complexes and reducing sugars. The reaction contributes to the decrease in L* values in cooking methods that involve higher temperatures and lower moisture levels, leading to darker, browned tomatoes. This reaction leads to the formation of a brown pigment known as melanoidin (Ghidurus *et al*., 2010).

The a* value of the tomato sample did not show a significant difference (p>0.05). Meanwhile, the b* value for all tomato samples is in the range of 21.48 - 33.65 and shows a significant difference (ANOVA p<0.05). A positive b* value indicates that the sample has a yellowish color. The baking method recorded a significantly high b* value of 33.65 ± 3.89 compared to the frying method (21.48 ± 0.35), but it was not significantly different (p>0.05) from the boiling method and frying with an air fryer. Meanwhile, the frying method recorded the lowest b* value significantly which is 21.48 ± 0.35, but it is not different (*p*>0.05) from boiling and frying with an air fryer. Changes in the value of b* due to the Maillard reaction occur in the presence of carbonyls (reducing sugars, ascorbic acid) and aldehyde products from lipid oxidation and free amine groups, namely lysine (Poojary & Lund, 2022).

Table 2. Colour (L*, a*, b*) of tomato undergoing different cooking treatments

Cooking method	Color		
	L*	a*	b*
Boiled (100°C, 6 min)	52.48 ± 0.93[a]	13.50 ± 3.60[a]	28.95 ± 4.88[ab]
Fried (230°C, 4.5 min)	34.85 ± 2.19[b]	12.81 ± 1.72[a]	21.48 ± 0.35[b]
Baked (175°C, 25 min	53.73 ± 7.89[a]	15.11 ± 5.00[a]	33.65 ± 3.89[a]
Air fried (200°C, 15 min)	55.72 ± 4.17[a]	12.72 ± 0.85[a]	30.44 ± 3.30[ab]

[a-b] Different letters indicate significant differences (*p*<0.05), within the same column.

Antioxidant properties

Antioxidant activity

Table 3 shows the antioxidant activity of tomato samples subjected to different cooking treatments. In this study, the frying method recorded the lowest antioxidant activity (free radical scavenging activity (DPPH) %) value of 71.01 ± 0.79% significantly (*p*<0.05) compared to other cooking methods. This result is consistent with the findings of Sahlin *et al*. (2004), who reported that frying caused the highest loss of antioxidants in tomatoes.

Table 3. Free radical scavenging activity (DPPH), total phenolic, lycopene, and ascorbic acid contents of tomato undergoing different cooking treatments

Cooking method	Free radical scavenging activity (DPPH) %	Total Phenolic Content (%)	Lycopene Content (mg/100 g)	Ascorbic Content (mg/100 g)
Boiled (100°C, 6 min)	76.67 ± 0.33[a]	5.95 ± 0.13[b]	79.92 ± 0.63[d]	0.17 ± 0.01[a]
Fried (230°C, 4.5 min)	71.01 ± 0.79[b]	9.96 ± 0.84[a]	97.05 ± 1.56[b]	0.12 ± 0.01[b]
Baked (175°C, 25 min	77.03 ± 1.26[a]	8.84 ± 0.43[a]	89.83 ± 1.35[c]	0.08 ± 0.02[c]
Air fried (200°C, 15 min)	74.62 ± 1.20[a]	4.83 ± 0.45[b]	103.35 ± 1.03[a]	0.05 ± 0.01[c]

[a-d] Different letters indicate significant differences (*p*<0.05), within the same column.

Thanuja *et al*. (2019) stated that the process of homogenization and heat treatment such as cooking can affect the cellular matrix and the cell wall of vegetables to release bound antioxidants and oxidative enzymes as well as hydrolytic enzymes. However, antioxidant activity depends on the type of vegetables and fruits. For example, Jiratanan and Liu (2004) reported that beets cooked at a temperature between 105°C to 125°C for 15 to 45 min increased the amount of antioxidant activity. However, green beans cooked under the same conditions have resulted in a decrease in the amount of antioxidant activity. In addition, based on the study of Wachtel-Galor et *al*. (2008) using broccoli and cauliflower, boiling can increase antioxidant activity probably due to the metabolic production of redox-active secondary plants.

Total phenolic content

The frying method and the baking method have recorded a significantly (*p*<0.05) higher amount (9.96 ± 0.84% and 8.84 ± 0.43%, respectively) of total phenolic content (Table 3) compared to the boiling method and the air fryer method (5.95 ± 0.13% and 4.83 ± 0.45%, respectively). Frying tomatoes affect their antioxidant properties through oxidation and thermal degradation of oil during frying (Erickson *et al*., 2023). Meanwhile, Palermo *et al*. (2014) reported that the Maillard reaction that occurs at temperatures of 160°C and above contributes to the reduction of phenolic content. In this study, the temperature of frying with an air fryer is as much as 200°C and has contributed to the Maillard reaction occurring.

According to Podsędek *et al*. (2008), phenolic content can be affected by cooking time and amount of water. Their study reported that there is a loss of 21% of the total phenolics when boiling red cabbage. Additionally, Sánchez-Rangel *et al*. (2013) and Maqbool *et al*. (2021) suggested that cooking can increase the rate at which cell wall degradation occurs and thus increase the bioavailability of phenolic compounds in tomatoes. This is caused by the softening and breaking of the cell wall in the tomato.

Lycopene content

Lycopene is one of the important carotenoids in tomatoes. Different cooking methods have been found to cause significant (p<0.05) differences in the lycopene content of tomato samples overall. The method of frying with an air fryer has recorded the highest lycopene content of tomato samples significantly (p<0.05) (103.35 ± 1.03 mg/100 g). The frying method recorded the second-highest lycopene content of the tomato sample (97.05 ± 1.56 mg/100 g), followed by the baking method (89.93 ± 1.35 mg/100 g). The boiling method recorded the lowest lycopene content (79.92 ± 0.63 mg/100 g). The findings of the study are in line with the results of the study of Mayeaux *et al*. (2006), who reported that frying can increase the temperature of tomatoes and cause a drastic decrease in moisture and lycopene content. This is because the high frying temperature can cause the oil to produce hydroperoxide free radicals and accelerate the degradation of lycopene in tomatoes. Compared to the method of frying with an air fryer, no oil is used and hydroperoxide free radicals are not produced. Therefore, the lycopene content by frying with an air fryer is higher than by oil frying.

Ascorbic acid content

There is a significant difference (p<0.05) for the ascorbic acid content overall. The boiling method was found to have the highest ascorbic acid content significantly (p<0.05) (0.17 ± 0.01 mg/100 g) compared to other cooking methods. The frying method has the second highest ascorbic acid content significantly (p<0.05) (0.12 ± 0.01 mg/100 g). This is followed by the baking method (0.08 ± 0.02 mg/100 g) and the air-fried method (0.05 ± 0.01 mg/100 g), with no significant difference (p>0.05) between these two methods.

According to MyFCD (2023), the content of ascorbic acid in tomatoes is 25.8 mg/100 g. The content of ascorbic acid in vegetables decreased after cooking was also proven by Chuah *et al*. (2008) in black pepper and Arkoub-Djermoune *et al*. (2016) in eggplant. For the frying method, the ascorbic acid content of tomato samples decreased due to high temperature, long cooking time, and enzymatic oxidation occurred during the preparation and frying process (Chuah *et al*., 2008). According to Bellili *et al*. (2019), the ascorbic acid content of tomatoes decreased due to the reduction of vitamin C content during cooking by accelerating the oxidation of ascorbic acid to dehydroascorbic acid, followed by hydrolysis to 2,3-diketogulonic acid. Eventually, polymerization occurs and causes the component to become inactive. Therefore, the loss of ascorbic acid content in cooked tomato samples is dependent on temperature, time, and the cooking method.

CONCLUSION

In conclusion, cooking methods such as boiling, oil frying, baking, and frying with an air fryer induce changes in physicochemical characteristics and antioxidant characteristics. In this study, different cooking methods showed a significant difference (p<0.05) for ash, color, pH value, and total soluble solids while cooking methods did not show a significant difference (p>0.05) for cooking loss, crude fiber, and firmness. There is a significant difference (p<0.05) in antioxidant activity, total phenolic content, lycopene content, and ascorbic acid content in tomatoes that have undergone different cooking treatments. Based on the analyses conducted in this study, air frying is the best cooking method to preserve the physicochemical properties of tomatoes with significantly higher values of ash, total soluble solids, color, antioxidant activity, and lycopene content, compared to other methods employed.

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ETHICAL STATEMENT

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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