Effects of Drying Temperature on Antioxidant Activities of Tomato Powder and Storage Stability of Pork Patties

Hyeong Sang Kim and Koo Bok Chin*
Department of Animal Science and Functional Food Research Center,
Chonnam National University, Gwangju 61186, Korea

Abstract
This study was performed to evaluate the antioxidant activity of oven-dried tomato powder (OTP) as affected by drying temperature and the effect of OTP on the product quality of pork patties. Three OTP products were obtained by drying of fresh tomato at 60, 80 and 100°C oven until constant weight was obtained. Total phenolic content of three kinds of OTPs ranged from 1.95 to 5.94 g/100 g. The highest amount of total phenolic compound was observed in OTP dried at 100°C. Antioxidant activity of three kinds of OTPs was measured by 1,1-diphenyl-2-picrylhydrazyl (DPPH)-radical scavenging activity, iron chelating ability, reducing power and measurement of lipid peroxide in linoleic acid emulsion system. In all parameters, OTP at 100°C showed the higher antioxidant activity than other temperatures (p<0.05). Based on the model study, the physicochemical properties, and antioxidant and antimicrobial activities of pork patties containing 1% OTP were measured. Redness of pork patties were increased with the addition of OTPs (p<0.05). Thiobarbituric acid reactive substances (TBARS) values of raw pork patties containing OTPs were lower than those of control (CTL) until 7 d of storage, regardless of drying temperatures (p<0.05). Peroxide values of pork patties made with OTP (1%) were lower than those of CTL until the end of storage time (p<0.05). However, no antimicrobial activities were observed among the treatments (p>0.05). Therefore, OTPs could be used as a natural antioxidant in meat products.

Keywords: Tomato powder, antioxidant activity, drying temperature, pork patty

Received November 4, 2015; Revised December 6, 2015; Accepted December 7, 2015

Introduction
Tomato is one of the most widely grown crops globally. Interest in tomato and tomato products is increasing due to their enriched phenolic contents and multiple bioactive functions (Kay et al., 2012). It has been well reported that oxidative stress of cell membranes and living tissues induced by reactive oxygen species resulted in various diseases (Niki, 2012). Lycopene is the most abundant carotenoid in tomato and tomato products and is responsible for their red color (Periago et al., 2009). In addition, tomatoes also contain anthocyanin, ascorbic acid and phenolic compounds, which have high antioxidant activity in humans (Chandra et al., 2012).

Tomatoes are a perishable vegetable and have to be consumed directly or processed (Latapi and Barrett, 2006). However, some tomato nutrients and antioxidant components may change with processing (Capanoglu et al., 2010). Heating, especially drying, is one of the most popular processing techniques that extend the shelf-life of products (Giovanelli et al., 2002). Although about 30% of ascorbic acid is degraded during drying (Zanoni et al., 1999), drying advantageously increases the phenol groups from cell wall phenolics (Lavelli et al., 1999). Phenolics in tomatoes remain stable under high temperature, and influence the high level of antioxidant activity (Dewanto et al., 2002).

Tomato products have been explored regarding improvement of the antioxidant property and to extend shelf-life of meat products (Candogan, 2002; Deda et al., 2007; Garcia et al., 2009; Domènech-Asensi et al., 2013). However, no studies have evaluated the antioxidant activity of tomato powder as affected by different drying temperatures. Therefore, the objective of this study was to evaluate the antioxidant activity of tomato powder dried at three different temperatures (60, 80 and 100°C) in model study and to investigate the antioxidant activity of pork...
Materials and Methods

Experiment I. Antioxidant activity of tomato powder with various drying temperatures

Materials

Fully ripened tomatoes (Lycopersicon esculentum Mill) were purchased from a wholesale market in Gwangju, Korea. Folin-Ciocalteu reagent, linoleic acid, ethylene diaminetetra acetic acid (EDTA), 1,1-diphenyl-2-pycrylhydrazyl (DPPH)-radical, and 2-thiobarbituric acid (TBA) were purchased from Sigma-Aldrich (Germany). Ferrous chloride, gallic acid, ferric chloride, petroleum ether, ascorbic acid, and trichloroacetic acid (TCA) were obtained from Junsei Chemical (Japan). Potassium ferricyanide was obtained from Avocado Research Chemicals (UK). Plate count agar and violet red bile agar were purchased from Difco (USA).

Drying of tomato powder

The tomatoes were washed, chopped, and homogenized prior to drying at 60, 80, or 100°C using a hot dry oven (LDO-250F, Labtech, Ltd., Korea). After drying at the drying temperatures (60, 80 and 100°C), 159.6, 138.8 and 132.5 g of OTPs were obtained from 2,884.6, 2,734.1 and 2,786.7 g of fresh tomato, respectively. The drying was completed until constant weight was obtained, and drying times and recovery yields of each powder were 20, 11 and 8 h, and 5.53, 5.08 and 4.75% for 60, 80 and 100°C, respectively. The obtained OTPs were kept at -70°C until utilized.

Determination of total phenolic content

The total phenolic compound of OTP from various drying temperatures was determined photometrically using Folin-Ciocalteu method (Lin and Tang, 2007). For analysis of total phenolic content, each OTP (0.1 g) was dissolved with 10 mL of distilled deionized (dd)-water. Then, 100 μL of each mixture was combined with 2.8 mL of dd-water, 2 mL of Na2CO3 (2%), and 0.1 mL of Folin-Ciocalteu reagent (50%). Optical density of each mixture was measured at 750 nm using a spectrophotometer (UV-1601, Shimadzu, Japan) after 30 min of incubating the mixture at room temperature. Total phenolic content was expressed as g gallic acid equivalents (GAE) per 100 g of OTP.

DPPH assay

The antioxidant activity was measured through the evaluation of free radical-scavenging activity on DPPH radical (Huang et al., 2006). Two milliliters of each solution (0.1-1% in dd-water) or ascorbic acid solution as a reference were mixed with 0.5 mL of methanolic DPPH (0.2 mM). The homogenate was vortexed and kept in darkness for 30 min. Subsequently, absorption of the samples was measured using a UV/VIS spectrophotometer (UV-1601, Shimadzu, Japan) at 517 nm. The final radical scavenging activity (%) was calculated as:

\[
\left( \frac{\Delta A_{517}}{\Delta A_{517} \text{ of control} - \Delta A_{517} \text{ of sample}} \right) \times 100
\]

Ferrous iron chelating ability

The antioxidant activity of OTP was also studied through the measurement of ferrous iron chelating ability (Le et al., 2007). A 0.6 mL volume of ferrous chloride reagent (0.1 mL) was mixed with 0.5 mL of sample (0.1-1% in dd-water) and methanol (0.9 mL). After 5 min, 0.1 mL of ferrozine (5 mM) was added and the sample was held for 10 min at room temperature. The ferrous chelating ability (%) was measured by measuring the absorbance of the Fe2+-ferrozine complex at 562 nm using a UV/VIS spectrophotometer (UV-1601, Shimadzu, Japan) and calculated as [(\(\Delta A_{562}\) of control – \(\Delta A_{562}\) of sample) \(\div\) \(\Delta A_{562}\) of control] \(\times\) 100. EDTA was used as the positive control.

Ferric reducing ability

The ferric reducing power reagent was prepared as described by Huang et al. (2006). The reagent was mixed with 2.5 mL of sample (0.1-1%). After 20 min of incubation at 50°C, 2.5 mL of trichloroacetic acid (TCA, 10%) was combined and the mixture was centrifuged for 10 min at 1,500 rpm. Subsequently, the upper layer (2.5 mL) was recovered and added to 2.5 mL of dd-water and 0.5 mL of ferric chloride (0.001%). Reducing power of samples was measured by reading the absorbance using a UV/VIS spectrophotometer (UV-1601, Shimadzu, Japan) at 700 nm.

Antioxidant activity in linoleic acid emulsion

Linoleic acid emulsion was prepared using the method described by Yen and Hsieh (1998). Approximately, 0.5 mL of each sample (0.1 and 0.5%) was combined with 2.5 mL of linoleic acid emulsion and 2 mL of phosphate buffer (0.2 M, pH 7.0). After incubation at 37°C, 0.1 mL of the mixture was taken every 24 h. At each time, 0.1
mL of sample solution was mixed with 4.7 mL of ethanol (75%), ammonium thiocyanate (0.1 mL, 30%), and ferrous chloride (0.1 mL, 0.02 M in 3.5% HCl). The mixture was held for 3 min at room temperature, and the absorbance at 500 nm using a UV/VIS spectrophotometer (UV-1601, Shimadzu, Japan) was recorded. Control and reference samples were prepared in the same way without the extracts and with butylated hydroxytoluene (BHT), respectively. A high optical density at 500 nm means low antioxidant activity.

Experiment II. Application of various tomato powder to pork patties

Patty preparation
Fresh pork hams and back fat was obtained from a wholesale meat market in Gwangju, South Korea. Trimmed lean and fat were grinded using a grinder (M-12s, Fujee Plant, Korea). Pork patties consisted of control, 0.1% ascorbic acid (reference), 1% T60, 1% T80, and 1% T100 (Table 1). Ground pork ham, pork back fat, sodium chloride, and three OTPs were mixed for 1 min (EF20, Crypto Peerles LTCL, UK), ground, weighed into 70 g portions, and formed into individual patties. The patties were placed a polystyrene plate and held at 4 ± 1°C for 14 d of refrigerated storage.

pH values and color measurement
pH measurements were performed by reading values with a pH-meter (MP-120, Mettler-Toledo, Switzerland). The color measurements of patty samples were performed with a color reader (CR-10, Minolta, Japan). Hunter L, a, and b values were determined as indicators of lightness, redness, and yellowness. All color measurements were done five times after the standardization of the instrument.

Volatile basic nitrogen (VBN)
VBN values of pork patties were measured with a slight modification by the method described by Conway (1962). Approximately 1 g of each mixed patty sample was homogenized with 9 mL of distilled water by homogenizer (S25N-18G, IKA, Germany) for 1 min at 11,000 rpm and filtered through Whatman No. 1 filter paper. A 1 mL volume of filtrate was transferred to a Conway dish and reacted with 1 mL of saturated K₂CO₃ solution and kept at 37°C for 120 min. The incubated solution was titrated with 0.01 N HCl and VBN value was expressed as mg%.

Thiobarbituric acid reactive substances (TBARS) and peroxide value (POV)
The extent of lipid oxidation was measured through the concentration of TBARS (Shinnhuber and Yu, 1977), and the results were expressed in mg of malondialdehyde (MDA) per kg of product. Two grams of patty samples were homogenized with 0.5 mL of antioxidant solution (comprised of BHA, BHT, propylene glycol, and Tween-20), 3 mL of 1% TBA solution, and 17 mL of 2.5% TCA solution. The mixture was heated in a boiling water bath for 30 min. Then, 5 mL of the upper layer and 5 ml of chloroform were mixed and centrifuged at 3,000 rpm for 5 min. After centrifugation, 3 mL of the supernatant was combined with 3 mL of petroleum ether. The mixture was centrifuged at 3,000 rpm for 10 min. The absorbance of the resulting reaction was recorded at 532 nm using a UV-1601 spectrophotometer (Shimadzu) and multiplied by a factor of 9.48 to obtain malondialdehyde concentration (mg/kg).

POV of pork patty samples was measured by the mod-

| Table 1. Formulation of pork patties with various tomato powders |
|---------------------------------------------------------------|
| Ingredients (%) | CTL | REF | T60 | T80 | T100 |
| Raw meat | 78.5 | 78.5 | 78.5 | 78.5 | 78.5 |
| Fat | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| Salt | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| AA | - | 0.1 | - | - | - |
| OTP dried at 60°C | - | - | 1.0 | - | - |
| OTP dried at 80°C | - | - | - | 1.0 | - |
| OTP dried at 100°C | - | - | - | - | 1.0 |
| Total | 100.0 | 100.1 | 101.0 | 101.0 | 101.0 |

AA = ascorbic acid; OTP = oven-dried tomato powder.

1/ Treatments: Control = patty without tomato extract; REF = patty containing 0.1% of AA; T60, T80 and T100 = patties containing 1% of OTP dried at 60, 80 and 100°C, respectively.
Total phenolic content

Total phenolic content of OTPs dried at the three different drying temperatures were summarized in Table 2. Their values ranged from 1.95 to 5.94 g per 100 g dry matter. The total phenolic content was significantly increased with increasing drying temperatures (p<0.05). OTP dried at high temperature, T100, showed the highest total phenolics as compared to other drying temperatures (p<0.05). The effect of heating on total phenolic compounds has been well studied. When tomato products are heated, the total polyphenol content is affected and increases with increasing drying temperatures (Santos-Sánchez et al., 2012). Kerkhofs et al. (2005) reported 8 to 33.4% of total polyphenols loss during the air-drying of tomato at 42°C, as compared to fresh tomato (p<0.05). Moreover, the loss varied appreciably with different cultivars (p<0.05). Heating has positively affects the bioaccessibility of total phenolics, resulting in release of phenolic compounds from the cell wall (Tulipani et al., 2012). They reported that phenolic composition of tomato sauces significantly differed from the raw tomatoes in their higher contents of rutin, naringenin, chlorogenic and neochlorogenic acid. This indicates that heat treatments may provide energy to break the linkage between phenolics and the insoluble polyesters of tomato fiber, potentially improved polyphenol bioaccessibility (Laguna et al., 1999). Vallverdú-Queralt et al. (2014) observed that major phenolic compounds of tomato sauce were ferulic acid, chlorogenic acid and caffeic acid. In addition, major flavonoids in tomato are rutin, quercetin and naringenin (Vallverdú-Queralt et al., 2011). In this study, the high drying temperature may have influenced the content of total phenolics, with a significantly higher content of total phenolic as compared to low drying temperatures (p<0.05). Although individual polyphenols were not measured in this study, changes of phenolic profile as affected by drying temperature and extraction solvent will be focused on the next study.

**Table 2. Content (g/100 g) of total phenolic compound from OTP as affected by different drying temperatures**

| Treatments  | T60 | T80 | T100 |
|-------------|-----|-----|------|
| Mean        | 1.95 | 3.59 | 5.94 |
| SD          | 0.05 | 0.04 | 0.06 |

*aMeans with different superscripts in the same row are different (p<0.05).

**Experiment I. Antioxidant activity of tomato powder with various drying temperatures**

- **Microbial counts**
  
  Ten grams of homogenized samples of pork patties were taken from each treatment, then mixed with 90 mL of sterilized dd-water and subsequently diluted. A volume of 0.1 mL of appropriately diluted sample was dispensed in duplicate onto total plate count (TPC) agar and violet red bile (VRB) agar for the incubation of total bacterial counts. Ten grams of homogenized samples of pork patties were taken from each treatment, then mixed with 90 mL of sterilized dd-water and subsequently diluted. A volume of 0.1 mL of appropriately diluted sample was dispensed in duplicate onto total plate count (TPC) agar and violet red bile (VRB) agar for the incubation of total bacterial counts.

- **Statistical analyses**
  
  For experiment I, two-way analysis of variance (ANOVA) was performed and data (n=3) were analyzed using SPSS 21.0 software (SPSS, USA) as factors for treatments (reference, T60, T80, and T100) and concentration (0, 0.1, 0.25, 0.5, and 1.0%). For experiment II, data (n=3) were analyzed by two factor factorial analysis using SPSS 21.0 program for Windows. The two factors were storage time (0, 3, 7, and 14 d) and five treatments (control, reference, T60, T80, and T100). Means were compared using the Duncan’s multiple range test at a 5% of significance level.

**Results and Discussion**

**Experiment I. Antioxidant activity of tomato powder with various drying temperatures**

**Total phenolic content**

Total phenolic content of OTPs dried at the three different drying temperatures are summarized in Table 2. Their values ranged from 1.95 to 5.94 g per 100 g dry matter. The total phenolic content was significantly increased with increasing drying temperatures (p<0.05). OTP dried at high temperature, T100, showed the highest total phenolics as compared to other drying temperatures (p<0.05). The effect of heating on total phenolic compounds has been well studied. When tomato products are heated, the total polyphenol content is affected and increases with increasing drying temperatures (Santos-Sánchez et al., 2012). Kerkhofs et al. (2005) reported 8 to 33.4% of total polyphenols loss during the air-drying of tomato at 42°C, as compared to fresh tomato (p<0.05). Moreover, the loss varied appreciably with different cultivars (p<0.05). Heating has positively affects the bioaccessibility of total phenolics, resulting in release of phenolic compounds from the cell wall (Tulipani et al., 2012). They reported that phenolic composition of tomato sauces significantly differed from the raw tomatoes in their higher contents of rutin, naringenin, chlorogenic and neochlorogenic acid. This indicates that heat treatments may provide energy to break the linkage between phenolics and the insoluble polyesters of tomato fiber, potentially improved polyphenol bioaccessibility (Laguna et al., 1999). Vallverdú-Queralt et al. (2014) observed that major phenolic compounds of tomato sauce were ferulic acid, chlorogenic acid and caffeic acid. In addition, major flavonoids in tomato are rutin, quercetin and naringenin (Vallverdú-Queralt et al., 2011). In this study, the high drying temperature may have influenced the content of total phenolics, with a significantly higher content of total phenolic as compared to low drying temperatures (p<0.05). Although individual polyphenols were not measured in this study, changes of phenolic profile as affected by drying temperature and extraction solvent will be focused on the next study.

**DPPH radical scavenging activity**

Effect of different drying temperatures of tomato on the DPPH radical scavenging activity is summarized in Table 3. Interactions between concentration of OTP and treatments were observed (p<0.05). Thus, the data were separated and their effects determined. Among the three OTPs, only DPPH radical scavenging activity of OTP at 100°C,
T100 was increased with increased levels of concentration ($p<0.05$). Their values were lower than the reference, ascorbic acid (AA) at all concentration ($p<0.05$). However, T100 showed the highest radical scavenging activity, among the treatments ($p<0.05$). High total phenolic content is highly related with DPPH radical scavenging activity (Sánchez-Moreno et al., 1998). Phenolic compounds are free radical terminators. They retard lipid oxidation by donation of a hydrogen atom to radicals (Shahidi et al., 1992). In this study, the highest drying temperature produced a significantly higher content of total phenolic compounds ($p<0.05$). Thus, increased phenolic antioxidants resulted in higher radical scavenging activity than low drying temperatures ($p<0.05$).

### Iron chelating ability

The ferrous chelating ability of the three powders is listed in Table 3. Their abilities increased with increasing concentration ($p<0.05$). Iron chelating abilities of all powders were lower than the EDTA reference from 0.1 to 0.5% ($p<0.05$). However, only tomato powder dried at 100°C, T100, showed similar chelating activity with EDTA ($p>0.05$). Among the treatments, T100 showed significantly higher iron chelating ability than those of T60 and T80 at 0.1-0.5% ($p<0.05$). The relationship of polyphenols with metal chelation ability has been reported by Brown et al. (1998). Furthermore, among the polyphenols, the presence of 3′, 4′-dihydroxy position in the B-ring or flavonoid. Due to this position, which has electron-donating ability, phenolic compounds have metal chelating ability (Andjelković et al., 2006). In this study, total phenolic compounds of OTP significantly increased with increasing drying temperature ($p<0.05$). Therefore, the high content of phenolic compounds of tomato powder dried at 100°C may contribute to higher iron chelating ability than those of lower drying temperatures.

### Reducing power

Reducing power of each OTP is summarized in Table 3. High optical density reflected high reducing power. All treatments showed an O.D value exceeding 0.5 at all concentrations, which is regarded as a high reducing power (Lin et al., 2009). As increasing concentrations, the reducing power of all treatments increased ($p<0.05$). All OTPs showed lower O.D values than that of AA at all concentrations ($p<0.05$). At lower concentrations (0.1-0.25%), the reducing power of T100 showed the highest value among the treatments, followed by T80 and T60 ($p<0.05$). However, no significant difference was observed between T80 and T100 at 0.5 and 1.0% ($p>0.05$). In the presence of reductones, antioxidants display reducing ability (Duh, 1998). These reductones donate a hydrogen atom to the radical and break the chain reaction (Gordon, 1990). Polyphenols including quercetin, tannic acid, gallic acid and caffeic acid are strong reducing agents; their increasing concentrations may increase reducing ability (Pulido et al., 2000). In this study, total phenolic content of OTP increased with increasing drying temperatures ($p<0.05$) indicating that increased reducing agent from OTP affected the reducing ability.

| Parameters                             | Treatments | Concentration (%) |
|----------------------------------------|------------|-------------------|
|                                        |            | 0.1               | 0.25             | 0.5              | 1.0              |
|                                        | AA         | 93.9$^{aA}$       | 93.5$^{aA}$      | 93.9$^{aA}$      | 94.4$^{aA}$      |
|                                        | T60        | 15.6$^{bB}$       | 17.9$^{bB}$      | 19.4$^{B}$       | 22.9$^{BC}$      |
|                                        | T80        | 23.4$^{B}$        | 26.5$^{B}$       | 27.6$^{B}$       | 35.4$^{BC}$      |
|                                        | T100       | 23.1$^{B}$        | 27.4$^{B}$       | 34.3$^{B}$       | 52.3$^{AB}$      |
| DPPH radical scavenging activity (%)  | EDTA       | 99.4$^{aB}$       | 99.6$^{aB}$      | 97.8$^{aA}$      | 99.8$^{aA}$      |
|                                        | T60        | 16.5$^{cC}$       | 18.1$^{cD}$      | 26.9$^{bcC}$     | 39.1$^{acC}$     |
|                                        | T80        | 14.6$^{dcC}$      | 23.6$^{bcC}$     | 35.7$^{bcC}$     | 51.7$^{BC}$      |
|                                        | T100       | 36.2$^{dcB}$      | 46.0$^{bcB}$     | 58.4$^{bcB}$     | 77.3$^{AB}$      |
| Iron chelating activity (%)            | AA         | 1.62$^{aA}$       | 1.91$^{aA}$      | 2.13$^{aA}$      | 2.22$^{aA}$      |
|                                        | T60        | 0.58$^{dD}$       | 0.93$^{dD}$      | 1.43$^{dC}$      | 1.69$^{dC}$      |
|                                        | T80        | 0.82$^{cC}$       | 1.37$^{BC}$      | 1.70$^{bB}$      | 1.74$^{BC}$      |
|                                        | T100       | 1.02$^{dD}$       | 1.62$^{dC}$      | 1.71$^{bB}$      | 1.76$^{dD}$      |
| Reducing Power (O.D)                   |            |                   |                   |                  |                  |

$^{a,b,c,d}$Means with different superscripts in the same row are different ($p<0.05$).

$^{A,B,C,D}$Means with different superscripts in the same column are different ($p<0.05$).

$^{1)}$Treatments: AA= L-ascorbic acid; T60= OTP at 60°C oven; T80= OTP at 80°C oven; T100= OTP at 100°C oven; EDTA = Ethylenediaminetetraacetic acid.
Antioxidant activity in linoleic acid emulsion

The antioxidant activities of OTPs with different drying temperatures in linoleic acid emulsion are presented in Fig. 1. High O.D. at 500 nm indicates the abundant formation of lipid peroxide. The O.D. value of the control increased continuously during incubation and the maximum amount of lipid peroxides was formed at 72 h. Further incubation time induced a production of low molecular lipid peroxide and resulted in the formation of secondary oxidation products. Formation of lipid peroxides was repressed with added OTPs during the incubation time. A 0.1% concentration of OTPs at 60 and 80°C showed higher lipid peroxide than 100°C treatment (p<0.05), but lower than control (p<0.05). Among the treatments, 0.1% of OTP at 60°C showed the lowest antioxidant activity (p<0.05). However, 0.1% of OTP at 100°C was comparable with the reference, 0.01% BHT. When tomato and tomato products are subjected to heat processing, the level of volatile compounds related to lipid oxidation increase. The most abundant volatile compounds from tomato pâtés is ester, and heat-induced components such as furfural, furans and acetaldehyde also were increased (Cosmai et al., 2013). Inhibition of the linoleic acid oxidation is strongly related with the phenolic compounds, which have antioxidant activity (Villares et al., 2012). Moreover, heating increases the level of phenolic compounds because of the release from cell wall phenolics (Lavelli et al., 1999). In this experiment, OTP from high temperature had higher total phenolic content than other treatments (p<0.05), and its higher antioxidant activity may decrease contents of lipid peroxide.

Experiment II. Evaluation of antioxidant and antimicrobial activity with water and ethanol extracts of tomato

pH and color

Since there was no interaction between treatment and storage days (p>0.05), data were pooled and separated as Table 4. Effects of three OTPs on the changes of pH and color of pork patties are summarized in Table 4. Addition of OTP decreased the pH values of pork patties (p<0.05) regardless of drying temperatures. During storage at 4°C, pH values did not change until 7 d (p>0.05). pH values of pork patty increased from 10 d (p<0.05) and the maximum value was observed at 14 d of storage (5.91) (p<0.05). Garcia et al. (2009) applied dried tomato peel to hamburgers and measured their physico-chemical and sensory properties. Hamburgers containing 6% of tomato peel displayed pH values that were significantly decreased compared to control (p<0.05). This result is close to the low pH values of added OTP (4.25, 4.14 and 4.01 for OTP at 60, 80 and 100°C, respectively). Thus, the various OTPs reduced the pH values of pork patties (p<0.05).

Pork patties with three OTPs showed different color patterns as compared to the control (Table 4). Only T100 displayed decreased lightness (p<0.05). Addition of OTP dried at 60 and 80°C increased redness (a) values, as compared to the CTL (p<0.05) and pork patties with OTP at 80 and 100°C displayed increased yellowness (b) values (p<0.05). During the storage time, increased lightness value and yellowness were evident due to the discoloration (p<0.05). Candogan (2002) added tomato paste on the beef patties and evaluated the effect of tomato paste on the quality characteristics of beef patties during 9 d of refrigerated storage at 4°C. He observed decreased lightness value, and increased redness and yellowness values with increasing tomato paste levels (p<0.05). This is a consequence of original tomato powder, which tended to lower color parameters as drying temperature increased from 60 to 100°C (data not shown). Therefore, addition of OTP with different drying temperatures changed color parameters of pork patties.

Volatile basic nitrogen (VBN)

Patties containing various OTP decreased VBN values as compared to the CTL (p<0.05), and similar with REF (p>0.05) (Table 4). During the storage, VBN value increa-
Tomato Powder as a Natural Antioxidant for Meat Product

Kim et al. (2013) reported similar results with this experiment. They added 0.25, 0.5, 0.75 and 1% of tomato extract with a solvent (hexane : acetone : ethanol = 50:25:25, v/v/v) from oven dried tomato powder and patties with tomato extract above 0.5% showed lower VBN value than the CTL on day 7 (p<0.05). Therefore, in this study, addition of tomato powder inhibited protein oxidation regardless of drying temperatures.

**TBARS and POV**

Since an interaction (p<0.05) between treatment and storage time was observed in the results of TBARS, data were separated out and assessed by treatment and a storage day (Fig. 2). TBARS values were increased (p<0.05) with increasing storage time in all treatments, except for the reference patty, containing 0.1% of ascorbic acid. During storage at 4°C in the refrigerator, TBARS values showed differences between treatments (p<0.05). From day 3, TBARS values of CTL increased and were significantly higher than the reference (p<0.05). As increasing storage days, more lipid oxidation was occurred in all patties except for the reference. Pork patties containing three OTP rapidly increased after day 7 (p<0.05). Patties with OTPs showed similar TBA values with CTL and OTP at 80 and 100°C showed lower TBA values than that of CTL (p<0.05).

Level of lipid peroxide of pork patties with three OTPs are shown in Fig. 3. POV of patty samples with three OTPs showed similar values during refrigerated storage (p>0.05). POV of all patty samples increased during storage, except for the REF (p<0.05). Significant differences of POV within samples were observed from 3 d. POV of samples with three OTPs was increased after 7 d, and their values lower than CTL and higher than the reference (p<0.05).

These results can be explained by antioxidant compounds from tomato, such as lycopene (Deda et al., 2007), which is a strong antioxidant and addition of tomato powder as

---

Table 4. Changes of pH, Hunter color values, VBN and microbial counts of raw pork patties with OTP powders during storage at 4°C for 14 d

| Parameters | Treatment | pH  | Hunter L | Hunter a | Hunter b | VBN  | TPC  | VRB  |
|------------|-----------|-----|----------|----------|----------|------|------|------|
|            | CTL       | 5.82<sup>a</sup> | 55.2<sup>b</sup> | 8.55<sup>b</sup> | 8.17<sup>b</sup> | 12.7<sup>a</sup> | 4.14<sup>a</sup> | 3.81<sup>a</sup> |
|            | REF       | 5.85<sup>a</sup> | 54.1<sup>b</sup> | 9.82<sup>b</sup> | 8.04<sup>b</sup> | 11.2<sup>b</sup> | 4.23<sup>b</sup> | 3.78<sup>b</sup> |
|            | T60       | 5.62<sup>b</sup> | 57.4<sup>a</sup> | 11.4<sup>a</sup> | 10.9<sup>b</sup> | 11.5<sup>b</sup> | 4.30<sup>a</sup> | 3.61<sup>a</sup> |
|            | T80       | 5.70<sup>b</sup> | 53.2<sup>b</sup> | 12.2<sup>a</sup> | 12.3<sup>a</sup> | 11.2<sup>b</sup> | 4.39<sup>a</sup> | 3.70<sup>a</sup> |
|            | T100      | 5.63<sup>b</sup> | 49.4<sup>a</sup> | 10.8<sup>b</sup> | 12.1<sup>a</sup> | 11.4<sup>b</sup> | 4.17<sup>a</sup> | 3.78<sup>a</sup> |

<sup>a-c</sup>Means with different superscripts in the same column (treatment) are different (p<0.05).

<sup>a-d</sup>Means with different superscripts in the same column (storage day) are different (p<0.05).

<sup>1</sup>Hunter L = lightness; Hunter a = redness; Hunter b = yellowness; VBN = volatile basic nitrogen (mg%); TPC = total bacterial counts (Log CFU/g); VRB = Enterobacteriaceae counts (Log CFU/g).

<sup>2</sup>Treatment: Control= patty without tomato extract; REF= patty containing 0.1% of AA; T60, T80 and T100= patties containing 1% of OTP dried at 60, 80 and 100°C, respectively.

---

![Fig. 2. TBARS of pork patties with various OTP as affected by different drying temperatures.](image-url)
natural additive can reduce TBA value of meat and meat products (Eyiler and Oztan, 2011). Although, tomato lipophilic antioxidant such as lycopene has strong antioxidant activity in meat products, tomato powder also has hydrophilic antioxidants, including phenolic compounds and flavonoids. By donating a hydrogen atom, lipid oxidation can be prohibited in meat products. Therefore, in this experiment, tomato antioxidants including phenolic compounds, flavonoids, and lycopene may increase antioxidant activity in pork patties.

Microbial counts

Microbial counts of patty samples with three OTPs are listed in Table 4. No interactions between treatment and storage day were observed in TPC and VRB \((p>0.05)\). No antimicrobial activity was observed in patties with three OTPs. During storage, total bacterial counts and number of \textit{Enterobacteriaceae} of pork patties rapidly increased from 7 d \((p<0.05)\). TPC showed higher than 6 Log CFU/g and VRB showed higher than 5 Log CFU/g from 10 d. Kim and Chin (2016) incorporated water soluble tomato powder (WSTP) from oven dried tomato powder as affected by different drying temperatures (60, 80 and 100°C) to pork patties. The authors reported that addition of three WSTPs decreased TPC and VRB of pork patty samples \((p<0.05)\). However, in this experiment, there was no antimicrobial activity with OTPs. Purification of water soluble fraction from tomato powder may increases antimicrobial compounds and may increases antimicrobial activity. Future study will be focused on the antimicrobial agent of tomato powder.

Conclusions

Total phenolic content of OTP was increased with increasing drying temperatures \((p<0.05)\). Increased drying temperatures increased DPPH radical scavenging activity, iron chelating ability and reducing power of tomato powder \((p<0.05)\). In linoleic acid emulsion system, OTP at 100°C showed the highest antioxidant activity as compared to other temperatures \((p<0.05)\). Addition of 1% OTP decreased pH values of pork patties \((p<0.05)\). Among the treatments, patties with 1% of OTP from 100°C oven-drying showed the lowest lightness value \((p<0.05)\). In contrast, incorporation of OTP into pork patties increased redness and yellowness values \((p<0.05)\). Patties with OTP products had lower VBN values than those of CTL. TBARS values of patties with OTP treatments were lower than those of control, but higher than those of the reference until 7 d of storage \((p<0.05)\). POV values of patties with OTP with various drying temperatures showed lower than those of control until the end of storage time \((p<0.05)\). However, no antimicrobial activity was observed among the treatments \((p>0.05)\). These results suggested that OTP could be used as a natural antioxidant in meat products during refrigerated storage.

Acknowledgements

This study was financially supported by National Research Foundation (NFR project #2014 009279).

References

1. Andjelković, M., Van Camp, J., De Meulenaer, B., Depaemeelaere, G., Socaciu, C., Verloo, M., and Verhe, R. (2006) Iron-chelation properties of phenolic acids bearing catechol and gallolyl groups. Food Chem. \textbf{98}, 23-31.
2. Brown, J. E., Khodr, H., Hider, R. C., and Rice-Evans, C. A. (1998) Structural dependence of avonoid interactions with Cu\(^{2+}\) ions: implications for their antioxidant properties. Biochem. J. \textbf{330}, 1173–1178.
3. Candogan, K. (2002) The effect of tomato paste on some quality characteristics of beef patties during refrigerated storage. Eur. Food Res. Technol. \textbf{215}, 305-309.
4. Capanoglu, E., Beekwilder, J., Boyacioglu, D., De Vos, R. C., and Hall, R. D. (2010) The effect of industrial food processing on potentially health-beneficial tomato antioxidants. Crit. Rev. Food Sci. Nutr. \textbf{50}, 919-930.
5. Chandra, H. M., Sharmugaraj, B. M., Srinivasan, B., and Ramalingam, S. (2012) Influence of genotypic variations on antioxidant properties in different fractions of tomato. \textit{J. Food Sci.} \textbf{77}, C1174-C1178.
6. Conway, E. J. (1962) Determination of volatile amines. In: Microdiffusion analysis and volumetric error. 5th ed, Ed by Conway, E. J., Crosby Lockwood, London, pp. 195-200.

7. Cosmai, L., Summo, C., Caponio, F., Paradiso, V. M., and Gomes, T. (2013) Influence of the thermal stabilization process on the volatilite profile of canned tomato-based food. J. Food Sci. 78, C1865-C1870.

8. Deda, M. S., Blouka, J. G., and Fista, G. A. (2007) Effect of tomato paste and nitrite level on processing and quality characteristics of frankfurters. Meat Sci. 76, 501-508.

9. Dewanto, V., Wu, X. Z., Adom, K. K., and Liu, R. H. (2002) Antioxidant activity of burdock (Arctium lappa Linne): Its scavenging effect on free-radical and active oxygen. J. Am. Oil Chem. Soc. 75, 455-461.

10. Domènech-Asensi, G., García-Alonso, F. J., Martínez, E., Santalla, M., Martin-Pozuelo, G., Bravo, S., and Periago, M. J. (2013) Effect of the addition of tomato paste on the nutritional and sensory properties of mortadella. Meat Sci. 93, 213-219.

11. Duh, P.-D. (1998) Antioxidant activity of burdock (Arctium lappa Linne): Its scavenging effect on free-radical and active oxygen. J. Am. Oil Chem. Soc. 75, 455-461.

12. Eyler, E. and Oztan, A. (2011) Production of frankfurters with tomato powder as a natural additive. LWT-Food Sci. Technol. 44, 307-311.

13. Garcia, M. L., Calvo, M. M., and Selgas, M. D. (2009) Beef hamburgers enriched in lycopene using dry tomato peel as an ingredient. Meat Sci. 83, 45-49.

14. Giovanelly, G., Zanoni, B., Lavelli, V., and Nani, R. (2002) Water sorption, drying and antioxidant properties of dried tomato products. J. Food Eng. 52, 135-141.

15. Gordon, M. H. (1990) The mechanism of the antioxidant action in vitro. In: B. J. F. Hudson (Ed.), Food Antioxidants, Elsevier, London, pp. 1-18.

16. Huang, S. J., Tsai, S. Y., and Mau, J. L. (2006) Antioxidant properties of methanolic extracts from Agrocybe cylindracea. LWT-Food Sci. Technol. 39, 378-386.

17. Kay, C. D., Hooper, L., Kroon, P. A., Rimm, E. B., and Cassidy, A. (2012) Relative impact of flavonoid composition, dose and structure on vascular function: A systematic review of randomised controlled trials of flavonoid-rich food products. Mol. Nutr. Food Res. 56, 1605-1616.

18. Kerkhofs, N. S., Lister, C. E., and Savage, G. P. (2005) Change in colour and antioxidant content of tomato cultivars following forced-air drying. Plant Food. Hum. Nutr. 60, 117-121.

19. Khokhar, S. and Apenten, R. K. O. (2003) Iron binding characteristics of phenolic compounds: some tentative structure-activity relations. Food Chem. 81, 133-140.

20. Kim, H. S. and Chin, K. B. (2016) Evaluation of different drying temperatures on physico-chemical and antioxidant properties of water-soluble tomato powders and on their use in pork patties. J. Sci. Food Agric. 96, 742-750.

21. Kim, I. S., Jin, S. K., Yang, M. R., Chu, G. M., Park, J. H., Rashid, R. H. I., Kim, J. Y., and Kang, S. N. (2013) Efficacy of tomato powder as antioxidant in cooked pork patties. Asian Australas. J. Anim. Sci. 26, 1339-1346.

22. Laguna, L., Casado, C. C., and Heredia, A. (1999) Flavonoid biosynthesis in tomato fruit cuticles after in vivo incorporation of 3H-phenylalanine precursor. Plant Physiol. 105, 491-498.

23. Latapi, G. and Barrett, D. M. (2006) Influence of pre-drying treatments on quality and safety of sun-dried tomatoes. Part II. Effects of storage on nutritional and sensory quality of sun-dried tomatoes pretreated with sulfur, sodium metabisulfite, or salt. J. Food Sci. 71, S32-S37.

24. Lavelli, V., Hippeli, S., Peri, C., and Elstner, E. F. (1999). Evaluation of radical scavenging activity of fresh and air-dried tomatoes by three model reactions. J. Agric. Food Chem. 47, 3826-3831.

25. Le, K., Chiu, F., and Ng, K. (2007) Identification and quantification of antioxidants in Fructus lycii. Food Chem. 105, 353-363.

26. Lin, J. Y. and Tang, C. Y. (2007) Determination of total phe-nolic and flavonoid contents in selected fruits and vegetables, as well as their stimulatory effects on mouse spleenocyte proliferation. Food Chem. 101, 140-147.

27. Lin, L. Y., Liu, H. M., Yu, Y. W., Lin, S. D., and Mau, J. L. (2009) Quality and antioxidant property of buckwheat enhanced wheat bread. Food Chem. 112, 987-991.

28. Niki, E. (2012) Do antioxidants impair signaling by reactive oxygen species and lipid oxidation products? FEBS Lett. 586, 3767-3770.

29. Periago, M. J., Garcia-Alonso, J., Jacob, K., Olivares, A. B., Bernal, M. J., Iniesta, M. D., Martinez, C., and Ros, G. (2009) Bioactive compounds, folates and antioxidant properties of tomatoes (Lycopersicum esculentum) during vine ripening. Int. J. Food Sci. Nutr. 60, 694-708.

30. Pulido, R., Bravo, L., and Saura-Calixto, F. (2000) Antioxidant activity of dietary polyphenols as determined by a modified ferric reducing/antioxidant power assay. J. Agric. Food Chem. 48, 3396-3402.

31. Sánchez-Moreno, C., Larrauri, J. A., and Saura-Calixto, F. (1998) A procedure to measure the antiradical efficiency of polyphenols. J. Sci. Food Agric. 76, 270-276.

32. Santos-Sánchez, N. F., Valadez-Blanco, R., Gómez-Gómez, M. S., Pérez-Herrera, A., and Salas-Coronado, R. (2012) Effect of rotating tray drying on antioxidant components, color and rehydration ratio of tomato saladette slices. LWT-Food Sci. Technol. 46, 298-304.

33. Shahidi, F., Janitha, P. K., and Wanasundara, P. D. (1992) Phenolic antioxidants. Crt. Rev. Food Sci. Nutr. 32, 67-103.

34. Shantha, N. C. and Decker, E. A. (1994) Rapid, sensitive, iron-based spectrophotometric methods for determination of peroxide values of food lipids. J. AOAC Int. 77, 421-424.

35. Shinnhuber, R. O. and Yu, T. C. (1977) The 2-thiobarbituric acid reaction, an objective measure of the oxidative deterioration occurring in fats and oils. J. Japan Oil Chem. Soc. 26, 259-267.

36. SPSS. (2012). SPSS 21.0 for Windows. SPSS Inc. USA.

37. Tulipani, S., Huelamo, M. M., Ribaltu, M. R., Estruch, R., Fe-
38. Vallverdú-Queralt, A., Regueiro, J., de Alvarenga, J. F. R., Torrado, X., and Lamuela-Raventos, R. M. (2014) Home cooking and phenolics: Effect of thermal treatment and addition of extra virgin olive oil on the phenolic profile of tomato sauces. *J. Agric. Food Chem.* **62**, 3314-3320.

39. Vallverdú-Queralt, A., Medina-Remón, A., Andres-Lacueva, C., and Lamuela-Raventos, R. M. (2011) Changes in phenolic profile and antioxidant activity during production of diced tomatoes. *Food Chem.* **126**, 1700-1707.

40. Villares, A., Guillamón, E., D’Arrigo, M., Martínez, J. A., García-Lafuente, A., and Ramos, A. (2012) Kinetic study of the inhibition of linoleic acid oxidation in aqueous media by phenolic compounds. *Food Biophys.* **7**, 50-56.

41. Yen, G. C. and Hsieh, C. L. (1998) Antioxidant activity of extracts from Du-zhong (*Eucommiaulmoides*) toward various lipid peroxidation models in vitro. *J. Agric. Food Chem.* **46**, 3952-3957.

42. Zanoni, B., Peri, C., Nani, R., and Lavelli, V. (1999) Oxidative heat damage of tomato halves as affected by drying. *Food Res. Int.* **31**, 395-401.