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ARTICLE

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

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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-pycrylhydrazyl (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

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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 consume 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 tomatos 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; Doménech-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

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patties with dried tomato powders.

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 Na_2CO_3 (2%), and 0.1 mL of Folin-Ciocalteau 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:

$[(\Delta A_{517}$ of control $- \Delta A_{517}$ of sample$) \div \Delta A_{517}$ of control$] \times 100$.

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 Fe^{2+}-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 K_2CO_3 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 (%)	Treatments[1)]				
	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.

ified method described by Shantha and Decker (1994). A 0.3 g portion of sample was homogenized with 10 mL of chloroform : methanol (1:1, v/v) solvent at 13,000 rpm by homogenizer (S25N-18G, IKA, Germany). Then, 3.08 mL of 0.5% NaCL was transferred and centrifuged at 3,000 rpm for 5 min. A 2 mL volume of the lower phase transferred to glass tube and 1.33 mL of chloroform : methanol (1 : 1, vv), 25 uL of 30% ammonium thiocyanate, and 25 uL of iron (II) chloride solution were added. After 20 min of incubation, optical density was recorded at 500 nm. Level of lipid peroxide was expressed as milliequivalents of peroxide per kilogram of sample (meq/kg).

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 and *Enterobacteriaceae*, respectively. The agars were incubated at 37°C for 48-72 h under aerobic conditions. Results were expressed as $\log_{10}$ colony forming units per gram (CFU/g).

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 (AA 0.1%), 1% of T60, 1% of T80 and 1% of 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 bioaccessiblity 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,

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

		Treatments[1)]		
		T60	T80	T100
Total phenolic contents (g/100 g dry matter)	Mean	1.95[c]	3.59[b]	5.94[a]
	SD	0.05	0.04	0.06

[a-c]Means with different superscripts in the same row are different ($p<0.05$).
[1)]Treatments: T60= OTP dried at 60°C; T80= OTP dried at 80°C; T100= OTP dried at 100°C.

Table 3. Antioxidant activities of tomato powder as affected by different drying temperatures

Parameters	Treatments[1)]	Concentration (%)			
		0.1	0.25	0.5	1.0
DPPH radical scavenging activity (%)	AA	93.9^{aA}	93.5^{aA}	93.9^{aA}	94.4^{aA}
	T60	15.6^{aB}	17.9^{aB}	19.4^{aB}	22.9^{aC}
	T80	23.4^{aB}	26.5^{aB}	27.6^{aB}	35.4^{aBC}
	T100	23.1^{cB}	27.4^{bcB}	34.3^{bB}	52.3^{aB}
Iron chelating activity (%)	EDTA	99.4^{aA}	99.6^{aA}	99.7^{aA}	99.8^{aA}
	T60	16.5^{bC}	18.1^{bD}	26.9^{abC}	39.1^{aC}
	T80	14.6^{cdC}	23.6^{bcC}	35.7^{abC}	51.7^{aBC}
	T100	36.2^{cB}	46.0^{bcB}	58.4^{bB}	77.3^{aAB}
Reducing Power (O.D)	AA	1.62^{dA}	1.91^{cA}	2.13^{bA}	2.22^{aA}
	T60	0.58^{dD}	0.93^{cD}	1.43^{bC}	1.69^{aC}
	T80	0.82^{cC}	1.37^{bC}	1.70^{aB}	1.74^{aBC}
	T100	1.02^{cB}	1.62^{bB}	1.71^{aB}	1.76^{aB}

[a-d]Means with different superscripts in the same row are different (p<0.05).
[A-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 = Ethylendiaminetetraacetic acid.

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 *o*-dihydroxy polyphenols is related to metal ion chelating ability (Khokhar and Apenten, 2003). There is a metal binding site on 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.

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 were 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.

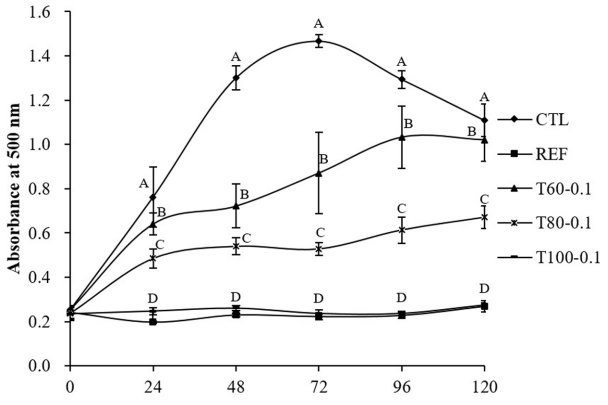

Fig. 1. Antioxidant activity of OTP as affected by different drying temperatures in linoleic acid emulsion. $^{A-D}$Means with having different superscripts within the same time are different (p<0.05). CTL = control; REF = reference (BHT 0.01%); T60-01 = 0.1% of OTP at 60°C; T60-0.5 = 0.5% of OTP at 60°C; T80-0.1 = 0.1% of OTP at 80°C; T80-0.5 = 0.5% of OTP at 80°C; T100-0.1 = 0.1% of OTP at 100°C; T100-0.5 = 0.5% of OTP at 100°C.

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 lightless (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-

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[1)]						
	pH	Hunter L	Hunter a	Hunter b	VBN	TPC	VRB
Treatment[2)]							
CTL	5.82^{a}	55.2^{ab}	8.55^{b}	8.17^{b}	12.7^{a}	4.14^{a}	3.81^{a}
REF	5.85^{a}	54.1^{ab}	9.82^{ab}	8.04^{b}	11.2^{b}	4.33^{a}	3.78^{a}
T60	5.62^{b}	57.4^{a}	11.4^{a}	10.9^{ab}	11.5^{b}	4.30^{a}	3.61^{a}
T80	5.70^{b}	53.2^{b}	12.2^{a}	12.3^{a}	11.2^{b}	4.39^{a}	3.70^{a}
T100	5.63^{b}	49.4^{c}	10.8^{ab}	12.1^{a}	11.4^{b}	4.17^{a}	3.78^{a}
Storage day							
0	5.64^{c}	52.3^{bc}	14.1^{a}	10.4^{a}	10.6^{b}	2.30^{d}	<2^{d}
3	5.65^{bc}	51.8^{c}	12.6^{a}	12.2^{a}	10.7^{b}	2.45^{d}	<2^{d}
7	5.69^{bc}	54.1^{abc}	10.1^{b}	9.76^{a}	11.2^{b}	3.78^{c}	3.01^{c}
10	5.74^{b}	55.7^{ab}	7.85^{b}	9.17^{a}	12.3^{a}	6.06^{b}	5.55^{b}
14	5.91^{a}	55.9^{a}	8.14^{b}	9.98^{a}	13.3^{a}	6.75^{a}	6.13^{a}

$^{a-c}$Means with different superscripts in the same column (treatment) are different (p<0.05).
$^{a-d}$Means with different superscripts in the same column (storage day) are different (p<0.05).
[1)]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).
[2)]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.

sed only at 10 d (p<0.05). 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

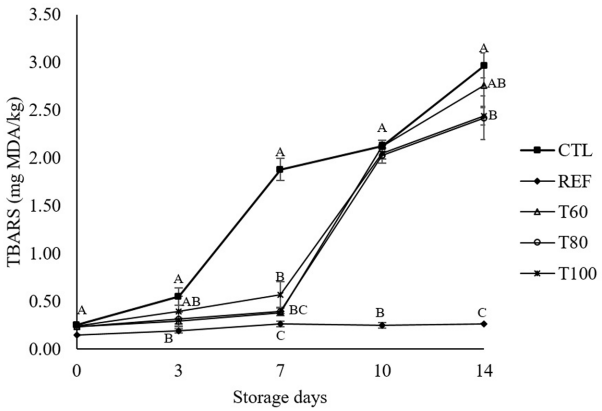

Fig. 2. TBARS of pork patties with various OTP as affected by different drying temperatures. $^{A-C}$Means with having different superscripts within the same storage days are different (p<0.05).

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 CTL increased from day 3, and maximum value was observed at 14 d (182 meq/kg). 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

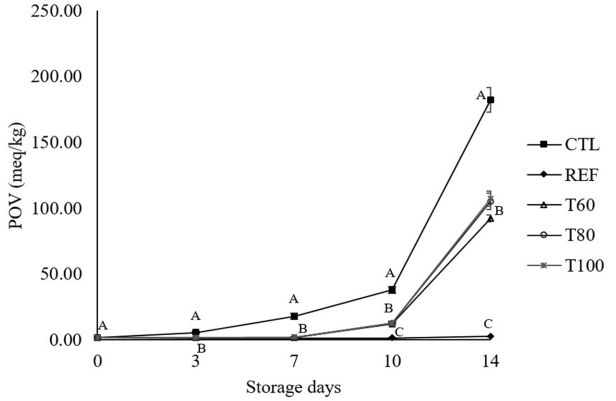

Fig. 3. POV of pork patties with three OTPs as affected by different drying temperatures. $^{A-C}$Means with having different superscripts within the same storage days are different (p<0.05).

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 *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.

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